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Spent Fuel and Waste Inventories and Projections

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SPENT FUEL AND WASTE INVENTORIES AND PROJECTIONS

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U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
Office of Nuclear Waste Management

PREFACE

This report was prepared under the Integrated Data Base Project, sponsored by the Office of Nuclear Waste Management, and reflects the integrated and coordinated input of the various lead offices and lead sites for Waste Products, Waste Isolation, Fuel Storage and Transfer, and Remedial Actions. The data contained herein constitute the official Department of Energy basis for overall inventories and projections, and are used in the National Plan for Radioactive Waste Management.

Since changes are continually occurring in both inventories and projections, this report will be updated periodically. In addition, future issues will contain added information to characterize the various spent fuel and waste types. Comments or suggestions for future issues are invited.

This report would not have been possible without the cooperation of the responsible lead offices and sites and their contributions, which were provided through the Steering Committee and technical contacts. These committee members and contacts are identified in the Appendix.

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SPENT FUEL AND WASTE INVENTORIES AND PROJECTIONS

ABSTRACT

Current inventories of commercial spent fuels and both commercial and U.S. Department of Energy radioactive wastes were compiled, based on judgments of the most reliable information available from Government sources and the open literature. Future waste generation rates and quantities to be accumulated over the remainder of this century are also presented, based on a present projection of U.S. commercial nuclear power growth and expected defense-related activities.

Spent fuel projections are based on the current DOE/EIA estimate of nuclear growth, which projects 180 GW(e) in the year 2000. It is recognized that the calculated spent fuel discharges are probably high in view of recent reactor cancellations; hence adjustments will be made in future updates of this report.

Wastes considered, on a chapter-by-chapter basis, are: spent fuel, high-level wastes, transuranic wastes, low-level wastes, mill tailings (active sites), and remedial action wastes. The latter category includes mill tailings (inactive sites), surplus facilities, formerly utilized sites, and the Grand Junction Project. For each category, waste volume inventories and projections are given through the year 2000. The land usage requirements are given for storage/disposal of low-level and transuranic wastes, and for present inventories of mill tailings.

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1. INTRODUCTION AND SUMMARY

1.1 Introduction

This study of radioactive waste inventories and projections has been made to compile a current, documented data-set for use in the planning and analysis of waste management functions and activities. Inventory and projection data have been obtained primarily from the lead offices that were established by the Department of Energy (DOE) to oversee the management of the various types of waste. In addition, published literature for approximately the past five years was reviewed to aid in the selection of the final data-set presented here.

Radioactive wastes originate from five major sources: (1) the commercial nuclear fuel cycle that is related to the production of electricity; (2) defense-related activities; (3) institutions such as hospitals, universities, and research foundations; (4) industrial uses of radioisotopes; and (5) mining and milling of uranium ores. The wastes are broadly characterized as low-level wastes (LLW), high-level wastes (HLW), and transuranic (TRU) wastes, depending upon the intensity of the radioactivity and/or the nature of the radioactive species that are present. Furthermore, the moratorium on nuclear fuel reprocessing interposes a large quantity of spent reactor fuel that, while technically not a waste, may require the construction of dedicated facilities for interim storage and/or permanent disposal if reprocessing is not reinstituted. In either case, a waste management plan must include both spent fuel inventories and projections.

The classes of nuclear materials that are discussed in this report are defined below:

Spent fuel is irradiated fuel discharged from a commercial reactor. The fuel assemblies are now stored in pools at the reactor sites and in pools at other locations.

Low-level waste is contaminated material that contains low, but potentially hazardous, amounts of radionuclides. However, the radiation level from these wastes may be high, requiring biological shielding for handling and transport. Low-level wastes may contain transuranic nuclides in concentrations no greater than 10 nanocuries per gram of material.

High-level waste originates in reprocessing irradiated fuel and is the aqueous waste from the first-cycle extraction system, or equivalent concentrated wastes from subsequent extraction cycles, or equivalent wastes from a process not using solvent extraction, in a facility for processing irradiated reactor fuels. High-level wastes may also be sludges, calcines, or other products generated in treating liquid high-level wastes. These wastes release considerable decay energy and require thick biological shielding for penetration emissions, as well as provisions for dissipation of the heat decay.

Transuranic waste, as defined by the AEC (now DOE), is material, excluding high-level waste, that is contaminated with certain alpha-emitting radionuclides of long-life and high specific radiotoxicity to a level of greater than 10 nanocuries per gram. The TRU waste classification includes all transuranic nuclides except ^{238}Pu and ^{241}Pu and, in addition, includes the ^{233}U isotope and its daughter products. Transuranic wastes result primarily from irradiated fuel reprocessing and the fabrication of plutonium. Generally, little or no biological shielding is required, but some TRU nuclides have energetic gamma and neutron emissions that require adequate shielding.

Mill Tailings are the earthen residues that remain after the extraction of uranium from ores. Tailings are generated in very large volumes and contain very low concentrations of naturally occurring radioactive materials. Mill tailings are low-level wastes but, because of their large volume, are discussed separately in this report.

Remedial action waste is contaminated material that results from decontamination and decommissioning activities to restore formerly utilized or surplus sites and facilities to unrestricted use. The DOE programs for these activities are the (1) Formerly Utilized Sites Remedial Action Program (FUSRAP), (2) Surplus Facilities Management Program (SFMP), (3) Uranium Mill Tailings Remedial Action Program (UMTRAP), and (4) Grand Junction Remedial Action Program (GJRAP). Remedial action wastes are predominantly low-level wastes, but some activities will produce TRU wastes as well. Since there are large quantities of these wastes which are program-specific, they are discussed separately herein.

The practice in managing high-level wastes has been to store them as aqueous solutions, salt cakes, and sludges in large underground tanks, or as calcined solids in bins. Millions of liters of HLW are in storage at DOE installations and at a commercial site at West Valley, N.Y. Future high-level wastes will be managed in the same manner until their final disposition has been established. As for low-level and transuranic wastes, the initial management practice was to place them in shallow-land burial at government facilities. During the 1950s, some industrial low-level wastes were disposed of by dumping at sea. Public reaction against sea-dumping caused the Atomic Energy Commission in 1960 to designate sites in various sections of the country that would be suitable for the disposal of industrial wastes. Some of these commercial sites did accept shipments of transuranic waste. Meanwhile, many AEC installations continued to dispose of both LLW and TRU wastes from defense-related activities by land burial. The Savannah River installation, however, did not accept TRU wastes. As a consequence of a growing concern for the effect of long-lived transuranic elements on the environment, the AEC issued a directive in 1970 that required all wastes containing >10 nCi of TRU elements per gram to be placed in retrievable storage, pending a decision on final disposition. Since that time, transuranic wastes have been packaged and stored on asphalt or concrete pads.

1.2 Summary

The reference growth rate of nuclear power in the United States currently projects 180 GW(e) of installed capacity in the year 2000. Two-thirds of this capacity will be pressurized water reactors (PWRs) and one-third boiling water reactors (BWRs). If no spent fuel is reprocessed, storage will be needed for about 195,200 BWR fuel assemblies and 122,600 PWR fuel assemblies in the year 2000 (Table 1.1). In addition, it is anticipated that by 2000 the United States will provide storage for approximately 3,490 fuel elements from foreign reactors, making a total of 321,300 fuel elements containing about 90,000 metric tons of uranium.

Table 1.1. Summary of projected accumulation of spent fuel[a]

Type of fuel	Calendar year ending			
	1980	1985	1990	2000
Boiling water reactor				
Number of assemblies	18,200	42,900	89,200	195,200
Metric tons uranium	3,170	7,630	16,000	35,200
Pressurized water reactor				
Number of assemblies	10,100	25,500	53,400	122,600
Metric tons uranium	4,290	11,100	23,400	53,800
Foreign				
Number of assemblies	0	1,520	3,490	3,490
Metric tons uranium	0	440	1,000	1,000
Total				
Number of assemblies	28,300	69,900	146,100	321,300
Metric tons uranium	7,460	19,200	40,400	90,000

[a]Based on installed U.S. nuclear capacities of 56.5, 167.4, and 180 GW(e) at the end of calendar years 1980, 1990, and 2000, respectively.

At the end of 1979, the estimated volume of HLW in storage at the DOE sites at Hanford, Savannah River, and Idaho, and at the Nuclear Fuel Services plant was 290,000 m^3 (Table 1.2). There is a projected increase of about 10% in this volume to 320,000 m^3 by 2000; the projection takes into account planned volume reduction procedures.

The quantities of LLW summarized in Table 1.2 consist almost entirely of contaminated solids that are disposed of by shallow-land burial. At the end of 1979, DOE LLW was about three times the volume of the LLW from the commercial and institutional — 1,778,000 m^3 as compared with 668,000 m^3. However, the projected growth of the nuclear fuel cycle and institutional and industrial activities is expected to produce more LLW by 2000 than DOE activities. The accumulated volumes by 2000 are estimated to be 7,436,000 m^3 and 3,233,000 m^3 respectively.

Table 1.2 also gives the estimated current and future volumes of TRU wastes. At the end of 1979, over 90% of these wastes were buried, and the quantity was almost equally divided between DOE and commercial burial sites. Beginning in 1970, burial of defense TRU waste was phased out over approximately a one-year period in favor of retrievable storage; and, in the period 1970 through 1979, an estimated 55,000 m^3 of solid materials contaminated with TRU nuclides were placed in retrievable storage at DOE sites. Defense-related and government-sponsored work is expected to produce an additional 101,000 m^3 of TRU wastes to total 147,000 m^3 on hand by 2000. A nominal 6,100 m^3 is estimated from industrial activities between 1980 and 2000; this must be placed in retrievable storage, probably at DOE sites.

The four remedial action programs (Table 1.3) of the DOE are expected to contribute considerable quantities — and some TRU wastes — during the remainder of this century. Only the Surplus Facilities Management Program (SFMP) will generate wastes that meet the DOE definition of TRU wastes. This program considers approximately 500 candidate facilities for restoration, if possible, to useful purposes. The major portion of SFMP waste will be produced in the midwestern United States.

Remedial action on inactive uranium mill tailings piles is carried out under UMTRAP, which must treat a larger volume of waste material than

Table 1.2. Summary of current waste inventories and projected accumulated volumes (10^3 m^3)

A. High-Level Wastes (HLW)

Year ending	Hanford[a]	Savannah River[a]	Idaho[b]	Nuclear Fuel Services[a]	Total
CY 1979	186	91	11	2.2	290
FY 1985	196	90	8.2		294
FY 1990	204	89	10		303
FY 2000	204	104	12		320

B. Low-Level Wastes (LLW)

	Commercial fuel cycle	Institutional and industrial	Total	DOE
CY 1979			668	1778
CY 1985	502	327	1500	2194
CY 1990	1210	599	2480	2540
CY 2000	2890	1240	4800	3233

C. Transuranic (TRU) Wastes

	DOE sites				
	Buried[c]	Retrievable storage	Buried at commercial sites[c]	Industrial activities[d]	Total
FY 1979	319	55	363		737
FY 1985	319	86	363	4.9	773
FY 1990	319	107	363	5.3	794
FY 2000	319	147	363	6.1	835

[a]Includes liquid, salt cake, and sludge.

[b]Includes liquid and calcine.

[c]Beginning in 1970, burial was phased out over an approximately one-year period in favor of retrievable storage.

[d]Must be sent to retrievable storage, probably at DOE sites.

Table 1.3. Summary of projected waste volumes from remedial action programs

A. Surplus Facilities Management Program (SFMP)

Low-level wastes (LLW)				Transuranic (TRU) wastes	
Regional distribution		Calendar	Accumulated	Calendar	Accumulated
Region	Volume (m^3)	year	volume (m^3)	year	volume (m^3)
East and South	32,000	1980	8,630	1980	550
Midwest	216,000	1990	138,500	1990	6,770
West	53,000	2000	301,000	2000	10,300
Total	301,000				

B. Uranium Mill Tailings Remedial Action Program (UMTRAP)

Site classification	Volume (10^3 m^3)	
	Tailings	Structures, equipment, etc.
High priority	6,570	2,410
Medium priority	4,710	670
Low priority	2,460	200
Total	13,740	3,280

C. Formerly Utilized Sites Remedial Action Program (FUSRAP)

Region	Volume (m^3)
East and South	313,800
Midwest	229,600
West	5,500
Total	548,900

D. Grand Junction Remedial Action Program (GJRAP)

	Status to April 30, 1980	
Number of structures to be rehabilitated by January 1, 1987	Number of structures rehabilitated or in progress	Waste volume (m^3)
800	375	42,700

the combined volumes of the other three programs. Where it is economical to do so, tailings piles will be processed to reclaim residual uranium; all piles will be stabilized to contain the other radionuclides. Twenty-five sites are identified under UMTRAP; all are in the western United States except the site at Canonsburg, Pennsylvania.

A total of 30 sites are included in the FUSRAP remedial action plans, and one-half of these are in the Northeast. The Grand Junction Remedial Action Program has been active since 1973 and includes the rehabilitation of approximately 800 structures that utilized uranium mill tailings in some phase of their construction. The volume of waste from the GJRAP is small in comparison to that from the other remedial action programs.

2. SPENT FUEL

2.1 Basis of Fuel Inventories

Projections of U.S. commercial spent fuel inventories were based on the "Proposed Reference Growth Scenario" of installed nuclear capacity (Table 2.1), and recommended for our use by DOE.[1] The DISFUL computer code[2] provided reactor-specific projected startup dates, core sizes, and historical and projected spent fuel discharges. The current and projected inventories of spent fuel are presented in Tables 2.2 and 2.3, and include estimates of foreign spent fuel eventually to be returned to the United States.[3]

The spent fuel discharge projections are somewhat high because of recent reactor cancellations which have not yet been accounted for in the DISFUL code, which was updated as of September 1979, corresponding to the projected capacity shown in Table 2.1 (182 reactors in 1994). At least nine reactors now in the DISFUL data base are known to have been cancelled. The DISFUL code will be updated again in late 1980, including new discharge schedules as well as the latest reactor build and start-up projections. Future editions of this report will incorporate the latest official data in this regard.

Table 2.1. Projected installed U.S. nuclear capacity[a]

Calendar year ending	Installed capacity [GW(e)]	Calendar year ending	Installed capacity [GW(e)]
1979	51.9	1990	167.4
1980	56.5	1991	172.4
1981	61.4	1992	174.8
1982	75.7	1993	177.2
1983	91.5	1994	178.5
1984	104.1	1995	178.5
1985	125.0	1996	178.5
1986	136.0	1997	178.5
1987	148.5	1998	178.5
1988	154.8	1999	178.5
1989	159.9	2000	180.0

[a]Data from ref. 1.

Table 2.2. Number of fuel assemblies to be discharged[a]

Calendar year	BWR[b]		PWR[c]		Foreign[d]		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1979		14,800		8,000				22,800
1980	3,455	18,255	2,060	10,060	0	0	5,515	28,315
1981	3,455	21,710	2,320	12,380	175	175	5,950	34,265
1982	4,035	25,745	2,430	14,810	175	350	6,640	40,905
1983	5,030	30,775	2,930	17,740	420	770	8,380	49,285
1984	5,635	36,410	3,680	21,420	420	1,190	9,735	59,020
1985	6,490	42,900	4,115	25,535	330	1,520	10,935	69,955
1990	10,055	89,250	6,160	53,400	0	3,490	16,215	146,140
1995	10,635	142,035	7,035	87,440	0	3,490	17,670	232,965
2000	10,635	195,210	7,035	122,615	0	3,490	17,670	321,315

[a]Data from ref. 3.

[b]Based on 0.181 MTU/assembly.

[c]Based on 0.440 MTU/assembly.

[d]Based on 0.287 MTU/assembly.

Table 2.3. Metric tons of uranium to be discharged as spent fuel[a]

Calendar year	BWR		PWR		Foreign		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1979		2,545		3,385		0		5,930
1980	625	3,170	905	4,290	0	0	1,530	7,460
1981	625	3,795	1,020	5,310	50	50	1,695	9,155
1982	730	4,525	1,070	6,380	50	100	1,850	11,005
1983	910	5,435	1,290	7,670	120	220	2,320	13,325
1984	1,020	6,455	1,620	9,290	120	340	2,760	16,085
1985	1,175	7,630	1,810	11,100	95	435	3,080	19,165
1990	1,820	16,010	2,710	23,360	0	1,000	4,530	40,370
1995	1,925	25,565	3,095	38,335	0	1,000	5,020	64,900
2000	1,925	35,190	3,095	53,810	0	1,000	5,020	90,000

[a]Data from ref. 3.

2.2 References

1. M. L. Lawrence, U.S. Department of Energy, communication to E. J. Wahlquist, U.S. Department of Energy, July 10, 1980, transmitting data from Energy Information Administration (EIA), Annual Report to Congress 1979, Vol. 3 (July 1980).
2. The S. M. Stoller Corporation, DISFUL Computer Code (September 1979).
3. U.S. Department of Energy, Spent Fuel Storage Requirements — The Need for Away-From-Reactor Storage, DOE/NE-0002 (January 1980).

3. HIGH-LEVEL WASTES

3.1 Sources

High-level wastes result from the chemical processing of irradiated nuclear fuels and targets. These high-level wastes contain more than 99% of the residual radionuclides produced in the fuels and targets during reactor operations. Most of the existing high-level wastes in the United States have been generated in defense activities [i.e., in producing plutonium and tritium for nuclear weapons at the DOE plants at Hanford and the Savannah River Plant (SRP), and in processing naval reactor fuels at the Idaho Chemical Processing Plant (ICPP)]. A small amount of commercial high-level waste has been generated from reprocessing reactor fuels at the Nuclear Fuel Services (NFS) plant.

3.2 Current Inventories

The high-level wastes now on hand are stored at four sites: the Hanford plant near Richland, Washington; the ICPP near Idaho Falls, Idaho; the SRP near Aiken, South Carolina; and the NFS plant at West Valley, New York. They originate as nitric acid solutions of fission product and actinide elements; however, they are often subsequently neutralized with caustic, which results in the formation of precipitated sludges. The supernatant liquid is then evaporated to form a salt cake. At the Hanford plant, most of the cesium and strontium are being chemically separated from the waste and stored separately, as dry solids, in sealed capsules. At the ICPP, acidic wastes are being calcined and stored as a dry granular product.

Approximately 288,000 m^3 of defense high-level wastes are currently in storage at the Hanford, Idaho, and Savannah River sites. Liquids, salt cake, and sludges constitute about 99% of the current volume, with calcine and cesium and strontium capsules representing the remainder. Approximately 2,200 m^3 of neutralized high-level wastes are stored in underground tanks at the NFS plant.

The inventory of high-level wastes, as of December 31, 1979, is shown in Table 3.1.

Table 3.1. Volumes of high-level wastes as of December 31, 1979 (10^3 m^3)

Site	Liquid	Salt cake	Sludge	Calcine	Separated Cs, Sr capsules	Total
DOE						
Savannah River Plant[a]	51.9	28.2	10.7	0	0	90.8
Idaho Chemical Processing Plant[b]	9.2	0	0	1.8	0	11.1
Hanford[c]	45.0	92.0	49.0	0	0.0011	186.0
Subtotal	106.1	120.2	59.7	1.8	0.0011	287.9
Commercial						
Nuclear Fuel Services[d]	2.2	0	0.04	0	0	2.2
Total	108.3	120.2	59.7	1.8	0.0011	290.1

[a]Data from ref. 1.

[b]Data from ref. 2.

[c]Data from ref. 3.

[d]Data from ref. 4.

3.3 Projected Inventories

An important part of formulating an overall high-level waste management strategy is the projection of future high-level waste generation rates and cumulative inventories. Since the reprocessing of commercial fuels has been deferred indefinitely, only defense wastes need to be considered. The long-term goal of high-level waste management is to immobilize and isolate these wastes from the biosphere. Present DOE programs are directed toward defining the final waste form and the method for ultimate isolation. It is planned to develop this technology and to be current in the immobilization and isolation of all high-level wastes by the year 2014.[5] The projected inventories for the three DOE sites are given in Table 3.2.

The volumes of liquid and calcined waste at the ICPP have been projected by their staff through FY 1991.[2] They were extrapolated from 1991 through the year 2000 for this report using the assumption that calcination will continue at an annual rate of 340 m^3/year (this is the average annual rate for 1986 through 1991), and that the liquid inventory will decline to zero by the year 2000.

Post-1990 Hanford waste volumes have been projected in the Technical Report on the Environmental Aspects of Long-Term Management of High-Level Hanford Defense Waste, and are consistent with the assumption that the N-Reactor operates through 1990 producing fuel-grade plutonium.[3] Consistent estimates of liquid, salt, and sludge volumes in 1980 and 1985 were derived from reference 7, while cesium and strontium capsule inventories during these years were assumed to progress linearly from the present inventory to the post-1990 value.

Table 3.2. Projected volumes of high-level defense wastes to be accumulated (10^3 m^3)

Calendar year ending	Liquid	Salt cake	Sludge	Calcine	Cs, Sr capsules	Total
			Savannah River[a]			
1980	51.5	25.7	11.0	-	-	88.2
1985	31.8	44.7	13.2	-	-	89.7
1990	19.7	54.9	14.8	-	-	89.3
1995	18.9	61.7	17.0	-	-	97.7
2000	22.3	64.3	17.0	-	-	103.7
			Idaho[b]			
1980	8.5	-	-	2.1	-	10.6
1985	4.7	-	-	3.5	-	8.2
1990	5.6	-	-	4.7	-	10.3
1995	4.6	-	-	6.7	-	11.3
2000	3.8	-	-	8.6	-	12.4
			Hanford[c,d]			
1980	39.0	95.0	49.0	-	0.0017	183.0
1985	50.0	95.0	51.0	-	0.0043	196.0
1990	52.0	95.0	57.0	-	0.0067	204.0
1995	52.0	95.0	57.0	-	0.0067	204.0
2000	52.0	95.0	57.0	-	0.0067	204.0
			Total			
1980	99.8	120.7	60.0	2.1	0.0017	281.8
1985	86.5	139.7	64.2	3.5	0.0043	293.9
1990	77.0	150.0	71.8	4.7	0.0067	303.6
1995	75.5	157.0	74.0	6.7	0.0067	313.0
2000	78.1	159.0	74.0	8.6	0.0067	320.1

[a]Data from ref. 6.

[b]Data from ref. 2.

[c]Data from ref. 7.

[d]Projected volumes are highly sensitive to schedule for startup of the Purex Plant.

3.4 References

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3. Rockwell Hanford Operations, Current Inventory Data, RHO-CD-14, Internal Document.
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4. TRANSURANIC WASTES

Most of the nuclides that comprise TRU wastes have very long half-lives and low specific activities. Although a few daughter products have energetic gamma emissions, most TRU wastes can be handled with just the shielding that is provided by the waste package itself. These wastes are classified as "contact handled" TRU wastes. A smaller volume may be contaminated with sufficient beta, gamma, or neutron activity that they must be handled remotely. Also, heat generation in stored TRU waste is not a factor affecting storage density, as is the case for wastes that contain large amounts of fission products.

4.1 Sources of TRU Wastes

Most TRU wastes are generated in defense-related activities of the DOE at Rocky Flats, Hanford, and the Los Alamos Scientific Laboratory. Smaller amounts are generated at the Oak Ridge National Laboratory, Savannah River Plant, Idaho National Engineering Laboratory, Argonne National Laboratory, Mound Facility, Bettis Atomic Power Laboratory, Lawrence Livermore Laboratory, and Battelle Columbus Laboratory. The amounts of TRU wastes from fuel cycle activities are quite small because of the current moratorium on reprocessing and plutonium recycle. The Nuclear Fuel Services' reprocessing of nuclear fuel at West Valley, N.Y., produced some TRU waste that was disposed of at that site.

A small amount of TRU waste is being generated in industrial and government-sponsored fuel fabrication and research. Sources of this waste are given in Table 4.1.

Table 4.1. Sources of industrial transuranic wastes

Babcock & Wilcox	(Apollo, Pa.)
Babcock & Wilcox	(Lynchburg, Va.)
Battelle Memorial Institute	(Columbus, Ohio)
Exxon Nuclear Company	(Richland, Wash.)
General Electric Company	(Vallecitos, Cal.)
Kerr-McGee Company	(Cimarron County, Okla.)
Monsanto Research Corporation	(Miamisburg, Ohio)
Nuclear Fuel Services	(Erwin, Tenn.)
Rockwell International	(Canoga Park, Cal.)
Westinghouse Corporation	(Cheswick, Pa.)

DOE programs concerned with management of surplus facilities, formerly utilized sites, and inactive mill tailings are expected to produce significant volumes of low-level wastes, some of which may contain TRU waste. These programs have recently been initiated and a number of sites and facilities have been identified that are candidates for reclamation. The Surplus Facilities Management Program (SFMP) has identified 514 facilities at 18 locations; the Uranium Mill Tailings Remedial Action Program (UMTRAP) has identified 25 inactive tailing piles; and the Formerly Utilized Sites Remedial Action Program (FUSRAP) has identified 30 sites that require remedial action. Discussion and inventories of TRU and low-level wastes from these programs are included in Sect. 7.

4.2 Current Inventories

An accurate assessment of the volume of TRU waste at DOE and commercial burial sites is difficult because early burial practices were not governed by the current definition of TRU waste. Studies have been made of early and more recent disposal practices in order to determine the amounts of these wastes that exist at the various disposal sites. Data from some of the studies are in relatively good agreement, but in some cases the difference between reported values is large.[1-10] A lead contractor for TRU waste management has been designated at the Rocky Flats plant to coordinate TRU activities at all DOE locations. This office has direct contact with the primary storage locations and has accumulated the most up-to-date inventory data and waste projections.

4.2.1 Buried transuranic defense wastes

Segregation of defense TRU wastes according to the current definition was not done when burial was practiced, and the values given in Table 4.2 are estimates of the amounts that have been emplaced. The table also includes estimates of the total subsurface volume (emplaced waste plus soil) that may be contaminated from leaking and ruptured containers. The uncertainty in these latter values may be quite large.

In March 1970, an AEC policy directive[11] mandated that all future TRU wastes, as defined in Sect. 1, be placed in retrievable storage.

4.2.2 Buried transuranic industrial wastes

Six commercial burial grounds for nuclear wastes were licensed for operation in the years 1962 to 1971. During this period, operating sites were located at Beatty, Nevada; Maxey Flats, Kentucky; West Valley, New York; Sheffield, Illinois; Richland, Washington; and Barnwell, South Carolina. However, TRU waste disposal was never permitted at Barnwell. Disposal practices generally followed customary precedures for sanitary landfills, utilizing emplacement in long trenches followed by backfilling with an earthen overburden. However, sites were especially chosen for suitability for disposal of radioactive and/or chemically toxic materials.

Table 4.2. Estimated amounts of buried transuranic wastes at DOE sites

Burial site	Solid waste emplaced (m^3)	Solid waste contaminated subsurface volume (m^3)	Mass of TRU elements (kg)
Hanford	211,251[a]	291,103[b]	371[c]
INEL	57,113[d]	212,859	381[e]
LASL	11,485[f]	28,300	13[g]
NTS	5,700[h]	5,700[i]	0.23[j]
ORNL	6,229[k]	167,072[k]	13[g]
SRP	27,270[l]	61,000[l]	7[g]
Pantex	33.4[m]	33.4[i]	
Sandia	3[m]	3[i]	0.0001[j]
Total	319,084	766,070	785.2

[a]Data from ref. 12.

[b]In addition there is an estimated 11 million cubic meters of contaminated soil from liquid waste disposal (ref. 13), containing over 200 kg plutonium.

[c]Data from ref. 14.

[d]Data from refs. 15 and 16; contaminated subsurface soil estimated to be 155,746 m^3 by H. M. Batchelder, EG&G/ID, and communication to L. J. Smith, RFP.

[e]Data from ref. 7.

[f]Data from ref. 10 updated to given value per communication between John Warren, LASL, and L. J. Smith, RFP.

[g]Data from ref. 5.

[h]Data from ref. 15 updated to given value per communication between G. Kindell, NTS, and L. J. Smith, RFP.

[i]No estimate made of volume of contaminated subsurface soil.

[j]Data from ref. 3.

[k]Data from ref. 15; contaminated subsurface volume estimated per communication between between E. King, ORNL, and L. J. Smith, RFP.

[l]Data from ref. 15; waste volume and contaminated subsurface volume updated per communication between O. Towler, SRP, and L. J. Smith, RFP.

[m]Data from refs. 15 and 16.

The physical form of the bulk of the waste at commercial burial grounds is paper trash, filters, broken glassware, cleaning aids, defective equipment, and much similar material whose surfaces have been in contact with TRU nuclides. At West Valley, where commercial fuel was processed, much of the transuranic material is in the drums containing hulls. The volumes of waste that might fall within the DOE definition of TRU waste at the various commercial burial sites are given in Table 4.3, along with estimates of the mass of TRU elements contained in these volumes. Commercial burial grounds have never segregated TRU-contaminated wastes from other wastes; thus the TRU inventory is mixed with large amounts of low-level waste. No TRU waste has been emplaced at commercial burial grounds since the early 1970s.

The waste volumes given in Table 4.3 are the estimated amounts of the low-level wastes at commercial burial grounds that might contain greater than 10 nCi of TRU activity per gram. The volumes in this table are also included in the inventory of low-level wastes given in Table 5.1.

Table 4.3. Estimated amounts of buried wastes at commercial burial sites that might meet DOE's TRU waste definition

Burial site	Buried volume (m^3)	Mass of TRU elements[a] (kg)
Beatty, Nev.	58,054[a]	14.3
Maxey Flats, Ky.	135,287[b]	69.1
Richland, Wash.	16,238[a]	23
Sheffield, Ill.	86,701[b]	13.4
West Valley, N.Y.	66,521[b]	3.6
Total	362,801	123.4

[a]Data from ref. 4; inventory through 1976.

[b]Data from ref. 10, Sect. 5.

4.2.3 Retrievable transuranic defense wastes

Since about 1970 all defense TRU wastes have been placed in retrievable storage at DOE facilities. This change in waste management practice was made because of concern for long-term effects of long-lived isotopes on the environment. The wastes are classified as "contact handled" or "remotely handled" according to the degree of their contamination with beta-gamma and possibly neutron activity. They are stored in standardized containers, except for certain bulky items, on asphalt or concrete pads. A filled storage pad is covered with a water-repellent material topped with about 1 m of soil.

A survey of DOE facilities conducted by the TRU waste lead contractor has estimated the quantities of wastes in retrievable storage. These data are given in Table 4.4 and represent the volumes emplaced as of the end of September 1979. Volumes are normally reported as the total container volume; however, SRP reports the volume of waste that is actually placed inside the storage container.

Table 4.4. Estimated amounts of transuranic defense waste in retrievable storage at DOE sites

Storage site	Volume emplaced as of October 1, 1979 (m^3)	Source of data
	Contact handled	
Hanford	8,038	Ref. 12
INEL	39,571	Ref. 15, 16[a]
LASL	3,528	Ref. 10
NTS	243	Ref. 15
ORNL	384	Ref. 15
SRP	2,365	Ref. 15
Total	54,129	
	Remotely handled	
LASL	73.5	Ref. 12, 15, 16
Hanford	0.8	ditto
INEL	19	ditto
ORNL	789	ditto
Total	882.3	

[a]Includes 1959 m^3 of packaged TRU waste that awaits emplacement, and does not appear in the references cited.

4.2.4 Retrievable transuranic industrial wastes

There is no estimate of the amount of TRU industrial waste that might be in retrievable storage. The volume of this waste, although small, in no way compares with the volume of defense waste. All those retrievable TRU industrial wastes that exist are at DOE disposal sites since commercial disposal sites have never practiced retrievable storage.

4.3 Projected Inventories

Estimates of the volumes of defense and commercial wastes that will require storage from the present to the year 2000 have been prepared. Projections that are not in the immediate future may have considerable uncertainty. For example, current projections are based upon no recycle of commercial fuel; however, if fuel reprocessing should be allowed within the next decade, the amount of TRU waste would be much larger.

4.3.1 Projections of transuranic defense wastes

The projected volumes of TRU defense wastes that will require retrievable storage at the six DOE sites are given in Tables 4.5 through 4.10. These estimates are current as of Oct. 1, 1979. The wastes are classified as contact handled or remotely handled.

Hanford. The TRU waste volumes that are expected to be emplaced at Hanford during the 1980-2000 time period are given in Table 4.5. The estimated uncertainty in the values is ±25%. The available storage capacity* at the Hanford site is 283,175 m^3, which is accessible without expansion of the area currently identified for this type of activity. This capacity is considerably more than the anticipated emplacement.

Idaho National Engineering Laboratory (INEL). The INEL receives TRU wastes from a number of installations throughout the country; the projected storage requirements for INEL are given in Table 4.6. The

* Available storage capacity is in addition to the capacity already utilized through September 1979; this comment also applies to available capacity values given in subsequent paragraphs.

Table 4.5. Projected storage of retrievable transuranic defense waste at Hanford[a]

	Contact handled		Remotely handled		
Fiscal year	Projected storage rate (m^3/year)	Accumulated volume (m^3)	Projected storage rate (m^3/year)	Accumulated volume (m^3)	Total accumulated volume (m^3)
1979	--	8,038	--	0.8	8,039
1980	696	8,734	739	740	9,474
1981	780	9,514	855	1,595	11,109
1982	289	9,803	855	2,450	12,253
1983	1,310	11,113	657	3,107	14,220
1984	405	11,518	653	3,760	15,278
1985	405	11,923	738	4,498	16,421
1986-1990	405	13,948	738	8,188	22,136
1991-1995	405	15,973	738	11,878	27,851
1996-2000	405	17,998	738	15,568	33,566

[a]Data from ref. 17. Data do not include receipts of TRU waste from off-site.

Table 4.6. Projected storage of retrievable transuranic defense waste at INEL[a]

Fiscal year	Contact handled: Projected storage rate (m^3/year)	Contact handled: Accumulated volume (m^3)	Remotely handled: Projected storage rate (m^3/year)	Remotely handled: Accumulated volume (m^3)	Total accumulated volume (m^3)
1979	-	39,571	-	19	39,590
1980	2,585	42,156	12.65	31.65	42,188
1981	2,658	44,814	12.05	43.70	44,858
1982	2,725	47,539	12.05	55.75	47,595
1983	2,882	50,421	11.05	66.80	50,488
1984	3,035	53,456	11.15	77.95	53,534
1985	2,777	56,233	11.15	89.10	56,322
1986-1990	2,152	66,993	10.15	139.85	67,133
1991-1995	1,914	76,563	10.15	190.60	76,754
1996-2000	1,914	86,133	10.15	241.35	86,374

[a]Data from ref. 13.

Table 4.7. Projected storage of retrievable transuranic defense waste at LASL[a]

Fiscal year	Contact handled: Projected storage rate (m^3/year)	Contact handled: Accumulated volume (m^3)	Remotely handled: Projected storage rate (m^3/year)	Remotely handled: Accumulated volume (m^3)	Total accumulated volume (m^3)
1979	-	3,528	-	74	3,602
1980	1,418	4,946	7	81	5,027
1981	568	5,514	7	88	5,602
1982-1985	568	7,786	7	116	7,902
1986-1990	568	10,626	7	151	10,777
1991-1995	568	13,466	7	186	13,652
1996-2000	568	16,306	7	221	16,527

[a]Data from ref. 13.

Table 4.8. Projected storage of retrievable transuranic defense waste at ORNL[a]

Fiscal year	Contact handled		Remotely handled		Total accumulated volume (m^3)
	Projected storage rate (m^3/year)	Accumulated volume (m^3)	Projected storage rate (m^3/year)	Accumulated volume (m^3)	
1979	-	384	-	789	1,173
1980	35	419	42.5	831	1,250
1981	71.8	491	70.8	902	1,393
1982–1985	71.8	778	70.8	1,185	1,963
1986–1990	71.8	1,137	70.8	1,539	2,676
1991–1995	71.8	1,496	70.8	1,893	3,389
1996–2000	71.8	1,855	70.8	2,247	4,102

[a]Data from ref. 13.

Table 4.9. Projected storage of retrievable transuranic defense waste at SRP[a]

Fiscal year	Contact handled[b]	
	Projected storage rate (m^3/year)	Accumulated volume (m^3)
1979	-	2,365
1980	146	2,511
1981–1985	146	3,095
1986–1990	146	3,825
1991–1995	146	4,555
1996–2000	146	5,285

[a]Data from ref. 13.

[b]The projected TRU waste at SRP does not include any remotely handled material.

Table 4.10. Projected storage of retrievable transuranic defense waste at NTS[a]

Fiscal year	Contact handled[b]	
	Projected storage rate (m^3/year)	Accumulated volume (m^3)
1979	-	243
1980	31.8	275
1981–1985	31.8	434
1986–1990	31.8	593
1991–1995	31.8	752
1996–2000	31.8	911

[a]Data from ref. 13.

[b]The projected TRU waste at NTS does not include any remotely handled material.

values include the wastes that will be shipped to INEL from Argonne National Laboratory (East), Bettis Atomic Power Laboratory, Mound Facilities, Rocky Flats, and Battelle Columbus Laboratories as well as the TRU waste that is produced at INEL. The Rocky Flats Plant (RFP) produces about 60% of the total waste. The values in the table are believed to be accurate within +20% to -40%. As at Hanford, there is ample TRU waste storage capacity at INEL without additional site expansion; the available capacity is 269,000 m^3.

Los Alamos Scientific Laboratory (LASL). The projected TRU wastes in Table 4.7 include the generation at Sandia, Lovelace Bioenvironmental Research Institute, and LASL. Greater than 99.5% of the total waste is produced at LASL, and the large decrease in generation after 1980 is due entirely to lower projections for LASL. However, the uncertainty in the generation rates is believed to be rather large, +150% to -25%. The available storage capacity at LASL that is currently approved is 12,740 m^3. The projected accumulation should not exceed this volume until late in the period 1996-2000.

Oak Ridge National Laboratory (ORNL). Projections for ORNL are given in Table 4.8 and include only the Paducah Gaseous Diffusion Plant and ORNL TRU wastes. The Paducah wastes are very small, estimated to be <1 m^3 per year of contact-handled material. The uncertainty in the ORNL projections is ±25%, and ORNL has available storage capacity for 1200 m^3 of TRU waste. Accumulation of contact handled and remotely handled wastes over the next 20 years is projected to be about 2930 m^3, a volume that exceeds the approved storage capacity. Storage space at ORNL will be exhausted in the 1986-1990 period, and additional sites would be needed for continuation of storage operations.

Savannah River Laboratory (SRP). Only TRU wastes generated at SRP are stored on that site. The projections to the year 2000, which are given in Table 4.9, include only contact handled material. The estimated uncertainty in the projections is ±50%. The additional accumulation from 1980 to 2000 is about 2920 m^3, whereas available approved storage capacity is 6350 m^3.

Nevada Test Site (NTS). In addition to its own TRU wastes, the NTS receives waste from Lawrence Livermore Laboratory (LLL). The projected accumulation to 2000 is given in Table 4.10; approximately 28% of the volume will be from LLL. The uncertainty in these volumes is ±25%. The available storage capacity at NTS is 172,750 m^3, which is considerably more than projected requirements to the year 2000.

4.3.2 Projections of transuranic industrial wastes

TRU-contaminated wastes from industrial operations include wastes from work done under government contract and from private ventures. Through 1982, most of these wastes (Table 4.11) will be generated by government work involving fuel fabrication. Waste projections beyond 1983 are expected to be entirely from continuing private operations and to average about 76 m^3/year. It is not known at this time where future industrial TRU wastes will be stored.

Table 4.11. Projected generation of industrial transuranic wastes[a]

Year	Wastes generated in: Government work (m^3/year)	Wastes generated in: Continuing operations (m^3/year)	Accumulated volume (m^3)
1980	1,092	405	1,497
1981	1,165	493	3,155
1982	1,270	249	4,674
1983	6.2	80.9	4,761
1984-1985	-	76.4	4,914
1986-1990	-	76.4	5,296
1991-1995	-	76.4	5,678
1996-2000	-	76.4	6,060

[a]Data from ref. 18; projections as of January 1980.

4.4 Land Usage

The land area that is committed to the storage of TRU wastes is directly dependent upon the storage density employed at the emplacement site. TRU waste storage is not controlled by thermal characteristics because decay heat can always be dissipated to the surroundings from customary storage configurations.

4.4.1 Land usage for buried wastes

The burial density for TRU-contaminated waste that was emplaced prior to 1970 at Hanford[19] and INEL averaged about 2600 m^3/hectare. This value takes into account space that is needed for equipment access, the actual burial trenches, and variations in waste emplacement density due to bulk, physical dimensions and shape, etc. Assuming that this burial density applies to wastes at the five commercial sites (Table 4.3), total land usage for the sites is about 140 hectares (346 gross acres) through calendar year 1970. Occupied land area for the 319,084 m^3 of buried TRU defense waste given in Table 4.2 is 123 hectares (304 acres), based on an average burial density at all DOE sites of 2600 m^3/hectare.

4.4.2 Land usage for stored wastes

Since 1970, TRU wastes have been placed in near-surface retrievable storage, and it is estimated that there are 54,129 m^3 of contact handled waste and 882 m^3 of remotely handled waste stored in this mode (Table 4.4). Compact storage is achieved through the use of standardized containers that are stacked (4.6 m to 4.9 m high) in an orderly arrangement to give a gross storage density of about 24,500 m^3/hectare ($\sim$350,000 ft^3/acre). At this storage density, only about 2.2 hectares were committed to retrievable storage at the end of September 1979.

4.4.3 Projected land requirements

The land areas that need to be committed to TRU waste storage for defense and commercial operations through the year 2000 are given in Table 4.12 for each DOE storage site. The values do not include the area

Table 4.12. Projected land usage for retrievable storage of TRU wastes

Storage site	Cumulative land utilization (hectares) 1985[a]	1990	1995	2000
	Contact handled defense waste			
Hanford	0.49	0.57	0.65	0.73
INEL	2.29	2.73	3.12	3.51
LASL	0.32	0.43	0.55	0.66
ORNL	0.03	0.05	0.06	0.08
SRP	0.13	0.16	0.19	0.22
NTS	0.018	0.024	0.031	0.037
Subtotal	3.28	3.96	4.60	5.24
	Remotely handled defense waste			
Hanford	0.18	0.33	0.48	0.64
INEL	0.004	0.006	0.008	0.01
LASL	0.005	0.006	0.008	0.009
ORNL	0.05	0.06	0.08	0.09
SRP	b	b	b	b
NTS	b	b	b	b
Subtotal	0.24	0.40	0.58	0.75
	Industrial waste			
Site undetermined	0.21	0.23	0.24	0.26
Total	3.73	4.59	5.42	6.25

[a]The 1985 values include the cumulative land usage from 1970, the beginning of retrievable storage for TRU waste.

[b]None projected.

that will be required for TRU wastes generated in remedial action programs; these requirements are discussed in Sect. 7. The requirements were calculated for the projected waste volumes of Tables 4.5 through 4.11 using a storage density of 24,500 m^3/hectare.

4.5 Summary of Transuranic Waste Inventories and Projections

There have been two distinct phases in the management of TRU wastes. Prior to the issuance of the AEC directive[11] in 1970 that required TRU wastes to be placed in retrievable storage, these wastes were disposed of in shallow-land burial as low-level wastes, and a considerable volume was routed to commercial burial grounds. Table 4.13 shows that about 53% of the TRU waste produced through 1970 was sent to commercial sites. The AEC directive required that post-1970 TRU wastes be placed in retrievable storage to facilitate reclamation and treatment for permanent disposal, pending the adoption of firm waste management criteria. A total of about 55,600 m^3 of waste is now stored in this manner (Table 4.13) at six DOE sites.

The projected generation of defense and industrial TRU wastes through 2000 is summarized in Table 4.13, indicating that an additional 98,000 m^3 may be produced over the next 20 years. This estimate assumes that there will be no recycle of commercial fuel, but does not include TRU wastes that might be produced in remedial action programs. All of this waste must be placed in retrievable storage.

Table 4.13. Summary of defense and industrial transuranic waste inventories and projections

Waste type	Volume (m^3)	TRU elements (kg)
Buried TRU waste[a]		
Defense[b] (at DOE sites)	319,000	785
Industrial[c] (at commercial sites)	363,000	123
Total	682,000	908
Retrievable TRU waste as of Oct. 1, 1979		
Defense, contact handled[b] (at DOE sites)	54,100	
Defense, remotely handled[b] (at DOE sites)	882	
Industrial	Not available	
Total	54,982	

Projected amounts of TRU wastes (fiscal year basis)

	Volume (m^3) during 1980	Cumulative volume[d] (m^3) Through 1985	1990	1995	2000
Defense, contact handled[b]	4,900	26,100	43,000	58,700	74,600
Defense, remotely handled[b]	800	5,000	9,100	13,300	17,400
Industrial, contact handled[e]	1,500	4,900	5,300	5,700	6,100
Total		36,000	57,400	77,700	98,100

[a]The date of the inventory for buried TRU waste at DOE sites is late 1970. However, wastes containing TRU nuclides might have been emplaced at commercial sites into the early 1970s. Values do not include an estimated 11 million cubic meters of contaminated soil at Hanford resulting from early liquid disposal practices.

[b]Data from refs. 12, 15, 16, and 20. The values listed do not include an estimated 447,000 m^3 of soil that might be contaminated with TRU materials from leaking or ruptured waste containers. See Table 4.2.

[c]Data from ref. 4.

[d]Cumulative volume increase in addition to the 682,000 m^3 of buried and 54,982 m^3 of retrievable TRU waste inventory through 1979.

[e]Data from ref. 18.

4.6 References

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5. LOW-LEVEL WASTES

5.1 Sources

Low-level wastes (LLW) are generated wherever radioactive materials are handled. The nuclear fuel cycle generates greater than 50% of the commercial waste that is shipped to commercial burial sites; the remainder is generated by hospitals, medical schools, universities, radiochemical manufacturers, research laboratories, and other NRC and state radioactive materials licensees.

DOE and government contractors generate LLW via the nuclear weapons program, enrichment facilities, the Naval Reactor Program, and various research and development activities.

An additional source of LLW is the remedial action programs that are being initiated. These wastes will be produced by the decontamination, decommissioning, dismantling, etc., of surplus facilities and equipment (see Sect. 7).

5.1.1 Commercial fuel cycle wastes

The nuclear fuel cycle produces a variety of low-level solid and liquid wastes consisting primarily of combustible and noncombustible (compactible and noncompactible) trash, protective clothing, failed equipment, resins, filter sludges, filter cartridges, and process liquids.

The relatively small amounts of solid wastes generated by the "wet process" UF_6 conversion and at the DOE enrichment facilities are buried on-site, whereas solidified waste generated by "dry process" UF_6 conversion, fuel fabrication, and nuclear power stations are shipped to commercial shallow-land burial sites.

5.1.1.1 Conversion. There are currently two commercial plants that convert U_3O_8 to UF_6 for feed material to the enrichment plants.[1] One plant utilizes solvent extraction followed by hydrofluorination-fluorination (wet process), and the other plant uses only hydrofluorination and fluorination to produce the gaseous UF_6 (dry process).

Approximately 0.05 m^3 of waste per metric ton of uranium (MTU) is produced by the dry process,[2] and ∿0.26 m^3/MTU by the wet process.[3]

5.1.1.2 Enrichment. The enrichment plant increases the isotopic concentration of ^{235}U in the gaseous UF_6 produced by the conversion processes. At the present time, enrichment is accomplished in plants using the gaseous diffusion process. Radioactive low-level liquid and solid wastes are generated primarily as the result of equipment cleanout, equipment replacement, and uranium recovery.[3]

Future increases in enrichment capacity are expected to consider gaseous centrifuge facilities. A gas centrifuge enrichment plant is expected to generate large quantities of contaminated parts and material from failed machines. The GESMO* model plant has an annual capacity of 8750 MTSWU (metric tons of separative work units) and generates 110 m^3 of waste from a diffusion plant and 5600 m^3 from a centrifuge facility.[4] The solid wastes at the enrichment facilities are buried on-site.

5.1.1.3 Fabrication. The wastes generated at fuel fabrication facilities consist of process liquids, a large amount of calcium fluoride (CaF_2) from process waste treatment systems, and lesser amounts of miscellaneous wastes consisting of rags, clothing, floor sweepings, sump sludges, disposable filters, and filter residues.[5] The combustible waste is incinerated, and the uranium in the ash is recovered by acid leaching when economically feasible. The CaF_2 and ash are generally disposed on-site, while the other wastes are packaged and shipped to a shallow-land burial site.

It is estimated that the total volume of solid waste generated is approximately 3.0 m^3/MTU.[5] Based on a survey of several fuel fabrication facilities, the quantity of waste shipped ranged from 119 m^3/year to 2945 m^3/year.[6] The average shipment was approximately 1133 m^3/year, which corresponds to a generation rate of 2.27 m^3/MTU.

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*The Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in LWR's (Draft), WASH-1327 (August 1974).

5.1.1.4 Light water reactors. The annual volume of waste shipped to a disposal site for a typical BWR is 742 m^3 for a 1000-MW(e) precoat plant and 1422 m^3 for a 1000-MW(e) deep-bed plant.[6] The annual volume of solidified waste for a 1000-MW(e) PWR (with or without a condensate polishing system) is 609 m^3.[6]

5.1.2 Institutional and industrial wastes

Low-level wastes are contaminated biological waste, scintillation vials, solidified and absorbed liquids, and miscellaneous dry solids.[7] These wastes comprised approximately 49% of those shipped to commercial shallow-land burial sites in 1978, and are further identified as follows:[8]

Waste form	Volume, m^3
Institutional	
Biological	1,803
Scintillation vials	9,223
Solidified and absorbed liquids	1,461
Dry trash	8,761
Total	21,248
Industrial	
Miscellaneous	20,397

5.1.3 DOE wastes

The wastes generated by DOE contractors as the result of both defense and other research and development operations fall into six general categories: biological waste, contaminated equipment, decontaminated debris, dry solids, solidified sludge, and miscellaneous.[9] Almost all of these wastes are buried at DOE sites; however, 14 of the DOE contractors have shipped waste to commercial burial sites.

5.2 Current Inventories

5.2.1 Low-level wastes at commercial burial grounds

There are six commercially operated, low-level waste burial sites located at Maxey Flats, Kentucky; Beatty, Nevada; Sheffield, Illinois; Barnwell, South Carolina; West Valley, New York; and Richland, Washington. However, the burial of waste at the Maxey Flats, West Valley, and Sheffield sites has been suspended.

The EPA requested those states having commercial shallow-land burial sites to provide inventories of the wastes that were buried (Table 5.1).[10] The inventories given in Table 5.1 also contain the low-level, TRU-containing volumes given in Table 4.3. All low-level wastes at the three closed sites are believed to fall within the DOE definition of TRU wastes (compare Tables 4.3 and 5.2).

Table 5.1. Estimated inventory of low-level wastes at commercial burial sites as of Jan. 1, 1980[a]

Site	Status	Accumulated volume (m^3)
Barnwell, S.C.	Open	269,300
Beatty, Nev.	Open	73,898
Hanford, Wash.	Open	35,844
Maxey Flats, Ky.	Closed[b]	135,287
Sheffield, Ill.	Closed[c]	86,701
West Valley, N.Y.	Closed[d]	66,521
Total		667,551

[a]Data from ref. 10.

[b]Burial suspended on Dec. 27, 1977.

[c]Burial suspended on Apr. 8, 1978.

[d]Burial suspended on Mar. 11, 1975.

5.2.2 DOE low-level wastes

The DOE low-level wastes consist of an almost infinite variety of materials contaminated with radioisotopes.[11] They include cellulosic and plastic materials, ion exchange resins, animal carcasses, contaminated equipment, and building rubble.

The DOE burial sites can be divided into major and minor sites, depending on the type of radioactive material interred. On this basis, LASL, INEL, ORNL, Hanford, NTS, and SRP are designated as major sites that have received about 75% of the total volume buried to date. The minor sites (see footnote c of Table 5.2) have accommodated the remainder.

Table 5.2. Volume of low-level waste buried at DOE sites as of October 1, 1979[a]

Site	Volume[b] (m^3)
Hanford, Wash	464,800
Idaho Falls, Idaho	117,000
Los Alamos, N.M.	155,300
Oak Ridge National Laboratory, Tenn.	192,000
Savannah River, S.C.	336,500
Nevada Test Site, Nevada	57,020
Sandia Laboratory, N.M.	1,336
Other[c]	436,900
Total	1,760,856

[a]Data from ref. 12.

[b]These wastes include beta-gamma-contaminated TRU waste.

[c]These are wastes that are contaminated with uranium and are buried on-site at the following locations: Pantex, Texas; Fernald FMPC, Ohio; National Lead, Ohio; Oak Ridge Gaseous Diffusion Plant and Oak Ridge Y-12 Plant, Tennessee; Paducah Gaseous Diffusion Plant, Kentucky; Portsmouth Gaseous Diffusion Plant, Ohio; Lawrence Livermore Laboratory, California; and Brookhaven National Laboratory, New York.

Currently, about 83,200 m^3 of low-level waste per year is being buried at DOE sites, and the accumulated volume through December 1979 is about 1,761,000 m^3 (Table 5.2).[12]

5.3 Projected Inventories of Low-Level Wastes

5.3.1 Fuel cycle low-level wastes

Projections of the volumes of fuel cycle low-level wastes were based on the throughput of uranium in a particular process and the installed nuclear capacity. These variables were multiplied by the proper waste source term (Sect. 5.1) to give a waste quantity. The waste projections were based on the proposed reference growth scenario of 180 GW(e) of installed nuclear capacity in the year 2000.[13] Projected spent fuel discharges[13] were calculated by the DISFUL computer code,[14] and reactor-specific information was taken from the DISFUL data base.[15]

Three simplifying assumptions were used in the waste projections: (1) there were no uranium process losses, (2) no lead times for the front-end fuel cycle operations were taken into account, and (3) the waste source terms (Sect. 5.1) remained constant.

The generation of low-level waste from reactors was based on the average installed capacity for each year. In the case of BWRs, 64% of the installed capacity in the year 2000 was assumed to have deep-bed condensate polishing systems. The remainder was assumed to be of the precoat type.[6] The projected amounts of reactor wastes are shown in Table 5.3.

Table 5.3. Annual and accumulated volumes of LLW from reactor operations

Year	Volume of wastes (10^5 m^3) Annual	Accumulated
1979	0.37	0.37
1980	0.40	0.77
1985	0.92	4.07
1990	1.31	10.1
1995	1.40	17.0
2000	1.41	24.0

Fuel fabrication wastes were based on the yearly reactor charge data and the initial core requirements for each new reactor. Fuel fabrication requirements also considered fuel fabricated domestically for foreign reactors. The fabrication load for foreign reactors was determined by assuming an installed nuclear capacity for the world (excluding the U.S.) of 600 GW(e) in the year 2000,[16] of which the U.S. would only provide the initial core and two reloads for those reactors supplied by the U.S.[17] This load represents less than 20% of the total fuel fabrication load in the U.S. from 1980 through 2000. The projection of fuel fabrication wastes is shown in Table 5.4.

Enrichment wastes were based on separative work unit (SWU) requirements and a mix of gaseous diffusion and centrifuge enrichment capacities. Both the gaseous diffusion and centrifuge operations were assumed to operate at 0.2% tails over the range of these projections. Initial PWR core enrichment was set at 2.4%, and reload enrichments were set at 3.2%. Initial BWR core enrichment was set at 2.0%, and reloads were 2.7%. Gaseous centrifuge plants were assumed to come on-line in 1989 and represent 7.5% of the total separative work capacity in that year. This was increased to 13.9% in 1990, 19.5% in 1991, and 24.4% in 1992 to 2000. Enrichment services for foreign customers were accounted for in the projection (Table 5.5) by including near-term enrichment commitments and assuming capture of 25% of the world enrichment market.[18]

Table 5.4. Annual and accumulated volumes of LLW from fuel fabrication[a,b]

Year	Volume of waste (10^5 m^3) Annual	Accumulated
1979	0.07	0.07
1980	0.07	0.14
1985	0.17	0.76
1990	0.18	1.63
1995	0.18	2.54
2000	0.17	3.43

[a]LLW is assumed to be generated in the same year that the uranium is charged to the reactor.

[b]LLW from fabrication of foreign fuel is less than 20% of the total.

Table 5.5. Annual and accumulated volumes of LLW from enrichment operations[a,b]

Year	Annual (10^3 m^3)		Accumulated (10^3 m^3)	
	GD[c,d]	GC[d,e]	GD[d]	GC[d]
1979	0.12	0.00	0.12	0.00
1980	0.12	0.00	0.24	0.00
1985	0.29	0.00	1.32	0.00
1990	0.32	2.92	2.93	4.40
1995	0.31	5.65	4.49	31.0
2000	0.32	5.73	6.05	59.4

[a]Gaseous centrifuge capacity is 7.5% of the total capacity in 1989, 13.9% in 1990, 19.5% in 1991, and 24.4% in 1992–2000.

[b]LLW is assumed to be generated in the same year that the uranium is charged to the reactor.

[c]GD = gaseous diffusion.

[d]LLW from enrichment of foreign fuel is between 20 and 40% of the total.

[e]GC = gaseous centrifuge.

Fresh UF_6 conversion wastes were based on domestic requirements plus ∿8% of world requirements (Table 5.6).[17]

The total amount of low-level wastes to be generated by a once-through uranium fuel cycle (including export services) is shown in Table 5.7.

Table 5.6. Annual and accumulated volumes of LLW from UF_6 conversion[a,b]

	Volume of wastes (10^4 m^3)	
Year	Annual	Accumulated
1979	0.17	0.17
1980	0.16	0.33
1985	0.40	1.77
1990	0.46	3.89
1995	0.47	6.21
2000	0.49	8.62

[a]LLW is assumed to be generated in the same year that the uranium is charged to the reactor.

[b]LLW from conversion of foreign uranium is less than 10% of the total.

Table 5.7. Total volumes of LLW from the commercial nuclear fuel cycle

	Volume of wastes (10^5 m^3)	
Year	Annual	Accumulated
1979	0.46	0.46
1980	0.49	0.95
1985	1.13	5.02
1990	1.57	12.1
1995	1.69	20.5
2000	1.69	28.9

5.3.2 Institutional and industrial low-level wastes

Institutional contributors of low-level wastes are hospitals, medical schools, and colleges and universities. In 1978, the institutions contributed 2.12×10^4 m^3 of waste to commercial burial grounds.[8] Based on past waste generation data, the institutional wastes are assumed to increase at a constant rate of 640 m^3/year.[7] This constant rate increase results in 3.53×10^4 m^3 of low-level waste being sent to burial grounds in the year 2000.

Low-level wastes from industrial sources were found to be of the same magnitude in 1978 as wastes from institutions.[8] Based on this one data point, a conservative estimate of the projected volumes would be that they increase at the same rate that the institutional wastes increase. The total volumes generated by both institutional and industrial sources are shown in Table 5.8.

Table 5.8. Annual and accumulated volumes of LLW from institutional and industrial sources[a]

	Volume of wastes (10^4 m^3)	
Year	Annual	Accumulated
1979	4.3	4.3
1980	4.4	8.7
1985	5.1	32.7
1990	5.7	59.9
1995	6.3	90.3
2000	7.0	124

[a]Institutional and industrial sources each contribute about half of the totals.

5.3.3 DOE low-level wastes

The major DOE sites and operations offices are initiating programs and contingency plans for the purpose of projecting waste volumes and burial land requirements based on foreseeable programmatic requirements. However, because of the current lack of information, projected solid low-level waste generation rates were made based on constant rates for the period 1980 through 2000.

Table 5.9 shows projected DOE solid low-level wastes at the major sites for the period 1978 through 1985.[19] The projected annual generation rates are based on current treatment methods, and they are relatively constant. On this basis, a constant annual generation rate for all DOE solid low-level waste is projected for 1980 through 2000 as presented in Table 5.10. Based on these generation rates, the projected inventory of DOE low-level wastes is presented in Table 5.11.

5.4 Land Requirements

The land requirements for the shallow-land burial of low-level wastes are affected by the burial density (i.e., m^3 of waste emplaced per hectare of land area) and by the site plot utilization factor (ratio of the land area actually used for burial to the total land area of the site). These are, in turn, affected by the geologic and hydrologic characteristics of the site.

5.4.1 Present usage

The land areas that have been used and that are currently available at the six commercial shallow-land burial sites are presented in Table 5.12;[7] similar information for the major DOE sites is presented in Table 5.13.[19]

5.4.2 Future needs

The burial density for low-level waste is different for each of the major DOE sites (Table 5.14).[20] It is dependent on such factors as terrain, geology, hydrology, and land availability, all of which vary

Table 5.9. Projected DOE solid low-level waste annual generation and accumulated rates for the period 1978 through 1985[a]

DOE site	Generation rate (m^3/year)								
	1978	1979	1980	1981	1982	1983	1984	1985	Total
INEL	5,932	5,348	3,628	3,889	4,569	5,860	5,865	5,664	40,755
Hanford	9,910	13,260	9,110	8,920	8,660	8,810	9,200	9,350	77,220
Nevada	10,790	9,910	9,910	9,910	9,910	9,910	9,910	9,910	80,160
LASL	2,010	2,270	2,270	2,270	2,270	2,270	2,270	2,270	17,900
SRP	13,740	13,740	13,740	13,740	13,740	13,740	13,740	13,740	10,990
ORNL	2,320	2,270	2,270	2,270	2,270	2,270	2,270	2,270	18,210
Total	44,702	46,798	40,928	40,999	41,419	42,860	43,255	43,204	247,545

[a]The data presented in this table are a compilation of those presented in ref. 19 with an update[20] on the Hanford data and on the INEL data.[21] The INEL waste projections include 1389 m^3 of wastes from decontamination of surplus facilities (SFMP wastes): 916 in 1978 and 473 in 1979.

Table 5.10. Projected low-level wastes by DOE Field Office

DOE Field office	Annual generation rates (m^3)		
	1979[a]	1980[a]	1980 to 2000[b]
Albuquerque	10,650	20,400	15,520
San Francisco	6,700	1,360	4,030
Chicago	2,090	2,810	2,450
Idaho	5,860	3,630	4,750
Nevada	1,070	1,650	1,360
Oak Ridge	10,060	5,910	7,990
Pittsburgh N.R.	2,410	2,480	2,450
Richland	13,000	12,880	12,940
Savannah River	16,080	16,130	16,110
Schenectady N.R.	1,810	1,580	1,700
Total	69,730	68,830	69,300

[a]Data from ref. 12. Includes the waste generated at all locations administered by a particular field office..

[b]Annual generation rates are based on current treatment methods and an average of the 1979 and 1980 generation rates. The rates are assumed to be constant for the period 1981 to 2000.

Table 5.11. Projected DOE solid low-level waste inventory

Year	Generation rate (m^3/year)	Accumulated volume (10^3 m^3)
1980	68,830	1,847
1985	69,300	2,194
1990	69,300	2,540
1995	69,300	2,887
2000	69,300	3,233

Table 5.12. Status of land usage and availability at commercial burial sites[a]

Site	Status	Site size (hectares)	Land utilized (hectares)	Land available (hectares)
West Valley, N.Y.	Closed	8.9	5.8	0[b]
Maxey Flats, Ky.	Closed	102	66.8	35.2[c]
Sheffield, Ill.	Closed	8.9	$\sim$8.9	Nil[d]
Barnwell, S.C.	Open	104	39.2	64.8[e]
Richland, Wash.	Open	40.5	2.0	38.5[f]
Beatty, Nevada	Open	32	7.3	11.3[g]
Total		296	130	150

[a]Data from ref. 6.

[b]Burial suspended on Mar. 11, 1975.

[c]Burial suspended on Dec. 17, 1977.

[d]About 49 hectares adjacent to the site were purchased, and 32 hectares of this may be suitable for burial.

[e]Expansion of this site is planned, although the area available has not been determined.

[f]The 40.5-hectare site is part of 405 hectares which the state has leased from the federal government. The 364.5-hectare tract may be available for future waste burial.

[g]Approximately 162 hectares could be purchased and added to the site if expansion is allowed.

Table 5.13. Status of land usage and availability for solid low-level waste burial at the major DOE sites[a]

Site	Site size (hectares)	Land utilized (hectares)	Land available (hectares)
Idaho National Engineering Lab.	35.6	25.5[b]	4.1[c]
Hanford	d	16.5[e]	d
Los Alamos Scientific Lab.	36.4	14.8	10[e]
Savannah River Plant	80	43	31.5[f]
Nevada Test Site	42.5	6.1	36.4[g]
Oak Ridge National Lab.	27.5	2.4	3.5[h]

[a]Data from ref. 19.

[b]The 25.5 hectares contain low-level beta-gamma waste. In addition, about 2 hectares have been used for TRU waste burial.

[c]Approximately 4 hectares of the burial site are not usable for shallow-land burial.

[d]Because of the abundance of land at the Hanford site, the size of the current burial sites and the availability of land for future use are not well defined. There appears to be no problem in designating additional land for shallow-land burial as it is needed.

[e]Approximately 11.7 hectares are not usable for shallow-land burial.

[f]Approximately 5.5 hectares are not usable for shallow-land burial.

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

[h]Only about 21% of the burial site is usable because of the rough terrain.

Table 5.14. Solid low-level waste burial densities at the major DOE sites[a]

Site	Burial density (m^3/hectare)
INEL	20,000
Hanford	3,470
LASL	10,510
SRP	10,900
NTS	na[b]
ORNL	6,580
Average	10,300

[a]Data from ref. 19.

[b]A burial density is not applicable at NTS since burial is carried out in craters, etc.

from site to site. The burial densities range from 3470 m^3/hectare at Hanford to 20,000 m^3/hectare at INEL. For the purpose of this assessment, an average of 10,300 m^3/hectare is used to project the land requirements for the period 1980 to 2000 (Table 5.15).

A survey taken of five commercial burial sites indicated that the average burial density varied from 15,400 m^3/hectare to 31,500 m^3/hectare.[22] The overall average, 19,240 m^3/hectare, was used in making projections of the land requirements for the period 1980 to 2000 (Table 5.16).

5.4.3 Summary

The current low-level waste inventories, utilized burial ground area, and projections of generation rates and burial area required for the period 1980 to 2000 are summarized in Table 5.16 for commercial, industrial, and institutional wastes, and in Table 5.17 for DOE wastes.

Table 5.15. Projected land requirements for burial of DOE solid low-level wastes

Year	Annual land requirements (hectares)	Cumulative land requirements (hectares)
1980	7	179
1985	7	213
1990	7	247
1995	7	280
2000	7	314

Table 5.16. Summary of current inventories, projected generation rates, and land requirements for burial of commercial, industrial, and institutional low-level wastes

Calendar year	Waste generation: Fuel cycle, Annual rate (m^3/year)	Waste generation: Fuel cycle, Accumulated (m^3)	Waste generation: Non-fuel cycle[a], Annual rate (m^3/year)	Waste generation: Non-fuel cycle[a], Accumulated (m^3)	Total accumulated volume (m^3)	Burial ground area required[b] (hectares)
1979					668,000	130
1980	49,000	49,000	44,000	44,000	761,000	135
1985	113,000	502,000	50,600	327,000	1,500,000	178
1990	157,000	1,210,000	57,000	599,000	2,480,000	229
1995	169,000	2,048,000	63,400	903,000	3,620,000	288
2000	169,000	2,891,000	69,800	1,240,000	4,800,000	349

[a]Institutional and industrial low-level wastes.

[b]A burial density of 19,240 m^3/hectare is used for the period 1980-2000.

Table 5.17. Summary of inventories, projected generation rates, and land requirements for DOE low-level wastes

Calendar year	Generation: Annual rate (m^3/year)	Generation: Accumulated (10^3 m^3)	Burial ground area required[a] (hectares)
1979	-	1,778	173
1980	68,830	1,847	179
1985	69,300	2,194	213
1990	69,300	2,540	247
1995	69,300	2,887	280
2000	69,300	3,233	314

[a]Based on an average burial density of 10,300 m^3/hectare.

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6. MILL TAILINGS

Mill tailings are currently divided into two categories according to their status: (1) tailings at inactive sites, and (2) tailings at active sites. Tailings at inactive sites are managed by the Uranium Mill Tailings Remedial Action Project Office and are discussed in Sect. 7. This section considers only the total quantities of mill tailings that are presently at active sites and projections of the tailings that are to be generated at presently active or newly developed sites.

6.1 Sources

The purpose of milling operations is to extract and concentrate the uranium from the ore. The product is known as yellowcake, which is a mixture of diuranates and uranium oxides. It is obtained by either of two processes: the acid leach or the alkaline leach process. In 1976, the acid leach process accounted for 82% of the total product, while the alkaline leach process accounted for the remainder.[1] The principal waste stream from both processes is the tailings.

The tailings are the undissolved solid residues from the leaching operation. As much as 10% of the uranium and virtually all of its daughters are in the tailings. Process water and chemicals are routed with the tailings to retention ponds for natural evaporation and storage. During mill operation the tailings are diked and kept moist or covered with wastewater, process chemicals, and process slimes. After the mill has ceased operations, the wet tailings are allowed to dry by natural evaporation.

Generally, a metric ton of mill feed produces about 0.54 m^3 of dry tailings.[2] However, the assays of uranium ore and the mill recoveries vary with time, resulting in a changing amount of mill tailings per metric ton of recovered uranium. Commercial grades of ore for the near term are expected to be in the range of 0.13-0.15%, and mill recoveries will be in the range of 91 to 93%.[3] As a result, the volume of dry tailings varies from 453 to 525 m^3 per metric ton of recovered uranium.

6.2 Inventories

The mill tailings at active sites are located in the southwestern and western United States. Seventy-four percent of the milling capacity is in New Mexicc and Wyoming. The remaining 26% is located in Colorado, Utah, Texas, and Washington. At the beginning of 1978, the active mill sites had produced approximately 1.07 x 10^8 metric tons of tailings having a volume of about 5.78 10^7 m^3.[4]

6.3 Projections

Projected volumes of dry mill tailings were calculated based on the installed nuclear capacity shown in Table 2.1. Unconventional sources of uranium, such as the by-product recovery from phosphate ores, were not considered. It was also assumed that there would be no effects from the foreign market in the form of either exported or imported uranium.

Uranium recoveries and ore assays were assumed to change with time. In the period 1979-1984, the ore assay was set at 0.15% and a uranium recovery of 92.8% was assumed. From 1985 to 1989, the ore assay was 0.139% with a uranium recovery of 92.0%. From 1990 to 2000, the ore assay was 0.139% with a recovery of 91.8%.[3] The projection of the volume of dry mill tailings is given in Table 6.1.

Table 6.1. Annual and accumulated volumes of tailings from milling operations[a]

Year	Volume of tailings (10^8 m^3) Annual[b]	Accumulated[c,d]
1979	0.05	0.66
1980	0.04	0.70
1985	0.12	1.11
1990	0.14	1.75
1995	0.14	2.48
2000	0.15	3.20

[a]Amounts are based on the following ore assays and mill recoveries:

1979-1984 – 0.15% ore assay and 92.8% mill recovery;
1985-1989 – 0.139% ore assay and 92.0% mill recovery;
1990-2000 – 0.131% ore assay and 91.8% mill recovery.

[b]Tailings are assumed to be generated in the same year as the uranium is charged to the reactor.

[c]Includes the pre-1979 inventory of tailings at active sites.

[d]Data from ref. 4.

6.4 References

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2. M. B. Sears et al., Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "as Low as Practicable" Guides - Milling of Uranium Ore, Vol. 1, ORNL/TM-4903 (May 1975).

3. L. W. Koch, "Cost Trends," Proceedings of Executive Conference on Uranium Fuel Supply, p. 132, American Nuclear Society, LaGrange Park, Ill., 1978.

4. Draft Generic Environmental Impact Statement on Uranium Milling, Vol. 1, NUREG-0511 (April 1979).

7. REMEDIAL ACTION WASTES

Programs have been initiated to assess DOE and other sites for candidate facilities that require remedial action for restoring the site as near as possible to its original condition. Most of the radioactive wastes from these programs will be low-level waste, but some transuranic wastes will also be produced.

Remedial action activities are carried out in four major programs: (1) Uranium Mill Tailings Remedial Action Program (UMTRAP), (2) Formerly Utilized Sites Remedial Action Program (FUSRAP), (3) Surplus Facilities Management Program (SFMP), and (4) Grand Junction Remedial Action Program (GJRAP).

7.1 Uranium Mill Tailings Remedial Action Program (UMTRAP)

Mill tailings are currently divided into two categories according to their status: (1) tailings at active sites, and (2) tailings at inactive sites. The UMTRAP program includes only tailings at inactive sites; tailings at active sites were discussed in Sect. 6. The Uranium Mill Tailings Radiation Control Act of 1978 authorized the DOE to undertake the stabilization and control of mill tailings in a safe and environmentally sound manner and, where appropriate and practical, to reprocess existing tailings to extract residual uranium and other mineral values. The Act also specifies remedial action as required on properties in the vicinity of tailings sites.

UMTRAP has identified 25 inactive tailings sites as candidates for remedial action; all are located in the western United States except the site at Canonsburg, Pennsylvania. Approximately 1.37×10^7 m^3 of tailings (2.22×10^7 MT) are present at these sites, occupying an area of about 414 hectares.[1] In addition to the mill tailings, disposal may also be required of an estimated 3.28×10^6 MT of contaminated structures, equipment, and surroundings. At several sites the residual uranium content may be sufficient for economic recovery.

The Uranium Mill Tailings Remedial Actions Project has categorized the sites into three groups according to the risk level to the general public. The sites that cause the largest number of potential health effects are identified as "high-priority" sites and will be where the first remedial action efforts take place. Subsequent remedial action will be directed toward the "medium-" and "low-priority" sites. Table 7.1 identifies the sites and gives estimated quantities of contaminated materials that must be treated.

7.2 Formerly Utilized Sites Remedial Action Program (FUSRAP)

The objectives of FUSRAP are to decontaminate and restore to unrestricted use, if this is reasonably achievable, Manhattan Engineering District and Atomic Energy Commission (MED/AEC) sites that are no longer being utilized. Thirty FUSRAP sites that require some type of remedial action have been identified; 15 of these sites are located in the northeastern region of the country.

The estimated total volume of remedial action low-level waste from the 30 FUSRAP sites (Table 7.2) is about 550,000 m^3, and about 312,000 m^3 of this waste is in the northeastern region. The waste form is generally soil containing very small amounts of uranium and thorium ores that in some cases have been processed.

7.3 Surplus Facilities Management Program (SFMP)

The SFMP[3] includes approximately 500 DOE facilities that are surplus, or will become surplus, in the near future. These facilities, located throughout the United States and Puerto Rico, include such installations as reactors and support facilities, solid waste burial grounds, fuel reprocessing facilities, laboratory facilities, stacks, tanks, pipelines, waste treatment systems, ponds, cribs, ditches, and areas with uranium/thorium residues. The objective of SFMP is to decontaminate these facilities to permit other productive uses and, at the same time, to eliminate any potential hazards to public health and the environment. The predominant type of facility, constituting about one-half of the remedial action

Table 7.1. Estimated quantities of UMTRAP waste to be treated[a]

Tailings location	Tailings area (hectares)	Tailings volume (10^3 m^3)	Other[b] (10^3 MT)
	High-Priority Sites		
Canonsburg, Pa.	7.7	104	13.6
Salt Lake City, Utah	44.9	1059	388
Durango, Colo.	8.5	874	426
Shiprock, N.M.	29.1	930	464
Gunnison, Colo.	15.8	304	80
Grand Junction, Colo.	23.9	1071	318
Old Rifle, Colo.	5.3	197	9.1
New Rifle, Colo.	12.9	1522	
Riverton, Wyo.	29.1	507	209
Subtotal	177	6568	2408
	Medium-Priority Sites		
Mexican Hat, Utah	27.5	1240	
Naturita, Colo.	9.3	0.6	9.1
Lakeview, Ore.	12.1	73.3	105
Falls City, Tex.	59.1	1409	545
Tuba City, Ariz.	8.9	451	
Ambrosia Lake, N.M.	42.5	1465	
Green River, Utah	3.6	69.3	10.9
Subtotal	163	4708	670
	Low-Priority Sites		
Slick Rock (NC), Colo.	2.4	20.8	5.4
Slick Rock (UC), Colo.	7.7	197	18.2
Maybell, Colo.	32.4	1465	90.9
Monument Valley, Ariz.	4.1	620	
Belfield, N.D.	9.7		45.6
Bowman, N.D.	8.5		41.8
Converse County, Wyo.	2.0	105	
Lowman, Idaho	7.3	50.7	
Baggs, Wyo.	0.2	6.2	
Subtotal	74	2465	203
Total	414	13,741	3,280

[a] Data from ref. 1.

[b] Includes building, structures, equipment, surroundings, etc.

Table 7.2. Estimated volumes of FUSRAP low-level wastes[a]

State	(m^3)
Florida	1,600
Illinois	13,000
Iowa	1,200
Maryland	60,000
Massachusetts	100
Missouri	210,000
New Jersey	112,000
New Mexico	2,700
New York	140,000
Ohio	5,400
Oregon	2,800
Pennsylvania	150
Totals	548,950

[a]Data from ref. 2.

efforts, is that which has been used for liquid waste disposal (ponds, cribs, ditches, etc.).

The SFMP is a 20-year program that is scheduled to begin in FY 1980. Approximately 48% of the total projected waste volume is expected to be generated in the first five years of the program and to amount to about 4990 m^3 of TRU-contaminated material and 57,200 m^3 of LLW. The remainder of the TRU and low-level wastes are expected to be generated at a constant rate over the remaining 15 years of the program. Total TRU waste under the SFMP is estimated to be about 10,300 m^3 (Table 7.3), and the total low-level waste to be about 301,000 m^3 (Table 7.4).

Table 7.3 delineates projected TRU waste generation for the period 1980-2000 according to the jurisdictional field office of the DOE. Table 7.4 contains similar data for low-level waste. Table 7.5 presents estimates of the low-level wastes that will be generated as a part of this program in various states.

7.4 Grand Junction Remedial Action Program (GJRAP)

Between the years 1952 and 1966, several hundred thousand tons of uranium mill tailings were removed from the Climax Uranium Company's mill tailings pile in Grand Junction, Colorado, for use in construction material. In 1966 the Colorado Department of Health and the U.S. Public Health Service became officially cognizant of this situation and ordered the mill to stop releasing the tailings. Investigations relative to their use as a construction-related material were initiated; and early in 1970, the U.S. Surgeon General provided guidelines for determining the need for corrective action at the many locations throughout the area where the tailings had been used.

The GJRAP oversees corrective action for those structures where radiation exposures exceed the Surgeon General's guidelines for radon daughters. It is estimated that about 800 structures will require remedial action. During the period 1973-1980, rehabilitation was started or completed on 375 structures[5] with the generation of about 42,660 m^3 of low-level waste. No projection has been made of the additional

Table 7.3. Projected volumes of TRU waste to be generated by SFMP[a,b]

DOE field office	TRU waste volume (m^3) 1980	1981	1982	1983	1984	1985–1989	1990–1994	1995–2000
Albuquerque	351	260	425	563	538			
Chicago	56.6	326	28.3	28.3	0			
Idaho	0	42.5	0	0	0			
Oak Ridge	142	178	14.1	0	17			
Richland	0	70.8	643	671	84.9			
San Francisco	0	646	0	0	0			
Annual total	550	1523	1110	1262	640	1783	1783	1783
Accumulated total	550	1973	3083	4345	4985	6769	8552	10,335

[a]Data from ref. 4.

[b]Total TRU waste for SRP is estimated to be only 3 m^3 over the 20-year period.

Table 7.4. Estimated volumes of LLW to be generated by SFMP[a]

DOE field office	Waste volume (m^3) 1980	1981	1982	1983	1984	1985-1990	1990-1995	1995-2000
Albuquerque	980	445	1,660	1,700	1,570			
Chicago	1,800	3,550	76.5	142	255			
Idaho[b]	2,550	113	3,400	4,920	623			
Nevada	42.5	45.5	0	0	0			
Oak Ridge	2,890	2,950	113	226	261			
Richland	0	3,057	4,221	8,610	8,140			
San Francisco	368	368	1,100	425	646			
Annual total	8,630	10,500	10,600	16,000	11,500	81,300	81,300	81,300
Accumulated total	8,630	19,130	29,730	45,730	57,230	138,500	219,800	301,000

[a]Data from ref. 4.

[b]There is still some question about these figures.

Table 7.5. Estimated volumes, by state, of SFMP low-level waste to be generated[a]

State	Waste volume (m^3)
California	2,900
Idaho	12,000
Illinois	480
Missouri	210,000
Nevada	85
New Jersey	4,600
New Mexico	22,000
New York	12,000
Ohio	6,200
Pennsylvania	7,800
South Caroiina	400
Tennessee	6,400
Washington	16,000
Puerto Rico	570
Total	301,435

[a]Data from ref. 2.

volume of waste that will be generated; however, it is expected to be less than that which has already been produced.

The GJRAP is scheduled for completion at the end of CY 1986.

Remedial action on inactive mill tailings at Monticello, Utah, is under the direction of the GJRAP. All waste at this site is low level, and it is estimated that 730,000 m^3 of tailings and contaminated soil must be removed. The project is scheduled to start in 1983 and end in 1990.

7.5 References

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2. U.S. Department of Energy, Understanding Low-Level Radioactive Waste, a report issued by the Low-Level Waste Management Lead Office, IDO (March 11, 1980).

3. U.S. Department of Energy, Nuclear Waste Management Program Summary Document, DOE/NE-0008, pp. 168-72 (March 1980).

4. Letter from R. L. Miller, UNC Nuclear Industries, Richland, Wash., to A. F. Kluk, USDOE-HQ, subject: Waste Volume Preliminary Estimates FY 1980 through FY 2000 (Mar. 28, 1980).

5. Status Report on the Grand Junction Remedial Action Program for the Period January 1, 1980 - April 30, 1980, undocumented report issued by the GJRAP Program Office, Grand Junction, Colo.

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APPENDIX: STEERING COMMITTEE MEMBERS, TECHNICAL CONTACTS, AND DOE INFORMATION CONTACTS

Steering Committee for Integrated Data Base

Functional responsibility	Committee member	Technical Contact*	DOE field office
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