Chapter 2

Status and Evaluation of U.S. Department of Energy Activities and Plans

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Status and Evaluation of U.S. Department of Energy Activities and Plans

The public is only vaguely aware of the nature and extent of the waste and contamination problems at the Department of Energy (DOE) Nuclear Weapons Complex. In addition, the government's goals for cleanup of contaminated sites and safe management of radioactive and hazardous waste are defined in very broad, general terms. DOE is attempting to clarify this situation through its 5-year planning process and its activities in waste management and environmental characterization at thousands of contaminated sites throughout the Weapons Complex.

This chapter examines and evaluates DOE activity and planning in key areas that are directed toward either a better understanding of the problem or a more effective approach to solutions. These areas are environmental restoration, waste management, costs, priorities, public involvement, and technology. The status of current programs is discussed for each subject, followed by the Office of Technology Assessment (OTA) evaluation of those activities.

Although DOE continues to make progress in this monumental task, many obstacles hinder the selection and adoption of optimum and effective solutions. Over the long term, fundamental changes in the government's approach to cleanup of the Weapons Complex will be necessary, if publicly acceptable goals are to be achieved. In this chapter, OTA identifies some key obstacles and suggests possible avenues for change.

Photo credit: U.S. Department of Energy

***Oil* Retention Ponds at *Oak* Ridge prior to remedial action.**

ENVIRONMENTAL RESTORATION OF CONTAMINATED SITES

Status

Overview

The Nuclear Weapons Complex is a collection of enormous factories devoted to metal fabrication, chemical separation processes, and electronic assembly. Like most industrial operations, these factories have generated waste, much of it toxic. Forty-five years of nuclear weapons production have resulted in the release of vast quantities of hazardous chemicals and radionuclides to the environment. Evidence exists that air, groundwater, surface water, sediments, and soil, as well as vegetation and wildlife, have been contaminated at most, if not all, nuclear weapons sites (l).

Contamination of soil, sediments, surface water, and groundwater throughout the Weapons Complex is widespread (2, 3, 4). Almost every facility has confined groundwater contamination with radionuclides or hazardous chemicals (see app. A). All sites in nonarid locations probably have surface water contamination. Almost 4,000 solid waste management units (SWMUs)[1] have been identified throughout the Weapons Complex—many of which require some form of remedial action. Substantial quantities of radioactive and mixed waste have been buried throughout the complex, many without adequate record of their location or composition. DOE

[1]The Environmental Protection Agency has defined an SWMU as "including any unit at the facility from which hazardous constituents might migrate, irrespective of whether the units were intended for the management of solid and/or hazardous wastes" (Hazardous Waste Management System, Final Codification Rule, 50 Fed. Reg. 28702,28712 (1985) (codified at 40 CFR $$260-62,264-66,270-71, 280)). An SWMU could be a unit such as a landfill, land treatment unit, waste pile, surface impoundment, container, tank, or incinerator. See 42 U.S.C.A. 6924(v) (West Supp. 1990).

Table 2-l—Examples of Nuclear Weapons Site Contaminants and Mixtures[a]

Inorganic contaminants:

Radionuclides:
Americium-241
Cesium-134, 137
Cobalt-60
Plutonium-238, 239
Radium-224, 226
Strontium-90
Technetium-99
Thorium-228, 232
Uranium-234, 238

Metals:
Chromium
Copper
Lead
Mercury
Nickel

Other:
Cyanide

Organic contaminants:
Benzene
Chlorinated hydrocarbons
Methylethyl ketone, cyclohexanone, acetone
Polychlorinated biphenyls, select polycyclic aromatic hydrocarbons
Tetraphenylboron
Toluene
Tributylphosphate

Organic facilitators:[b]
Aliphatic acids
Aromatic acids
Chelating agents
Solvents, diluents, and chelate radiolysis fragments

Mixtures of contaminants:[c]
Radionuclides and metal ions
Radionuclides, metals, and organic acids
Radionuclides, metals, and natural organic substances
Radionuclides and synthetic chelating agents
Radionuclides and solvents
Radionuclides, metal ions, and organophosphates
Radionuclides, metal ions, and petroleum hydrocarbons
Radionuclides, chlorinated solvents, and petroleum hydrocarbons
Petroleum hydrocarbons and polychlorinated biphenyls
Complex solvent mixtures
Complex solvent and petroleum hydrocarbon mixtures

[a]The contaminant list is being upgraded as new information becomes available.
[b]Facilitators are organic compounds that interact with and modify metal or radionuclide geochemical behavior.
[c]Information on mixture types is sparse, and concentration data are limited.

SOURCE: U.S. Department of Energy/Office of Health and Environmental Research, Subsurface Science Program, Co-Contaminant Chemistry Subprogram, "Draft Strategy Document," March 1990.

has estimated that buried transuranic waste totals about 0.2 million cubic meters and buried low-level radioactive waste, 2.5 million cubic meters (5). Most of this buried radioactive waste is also mixed with hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA)[2] (so-called mixed waste).

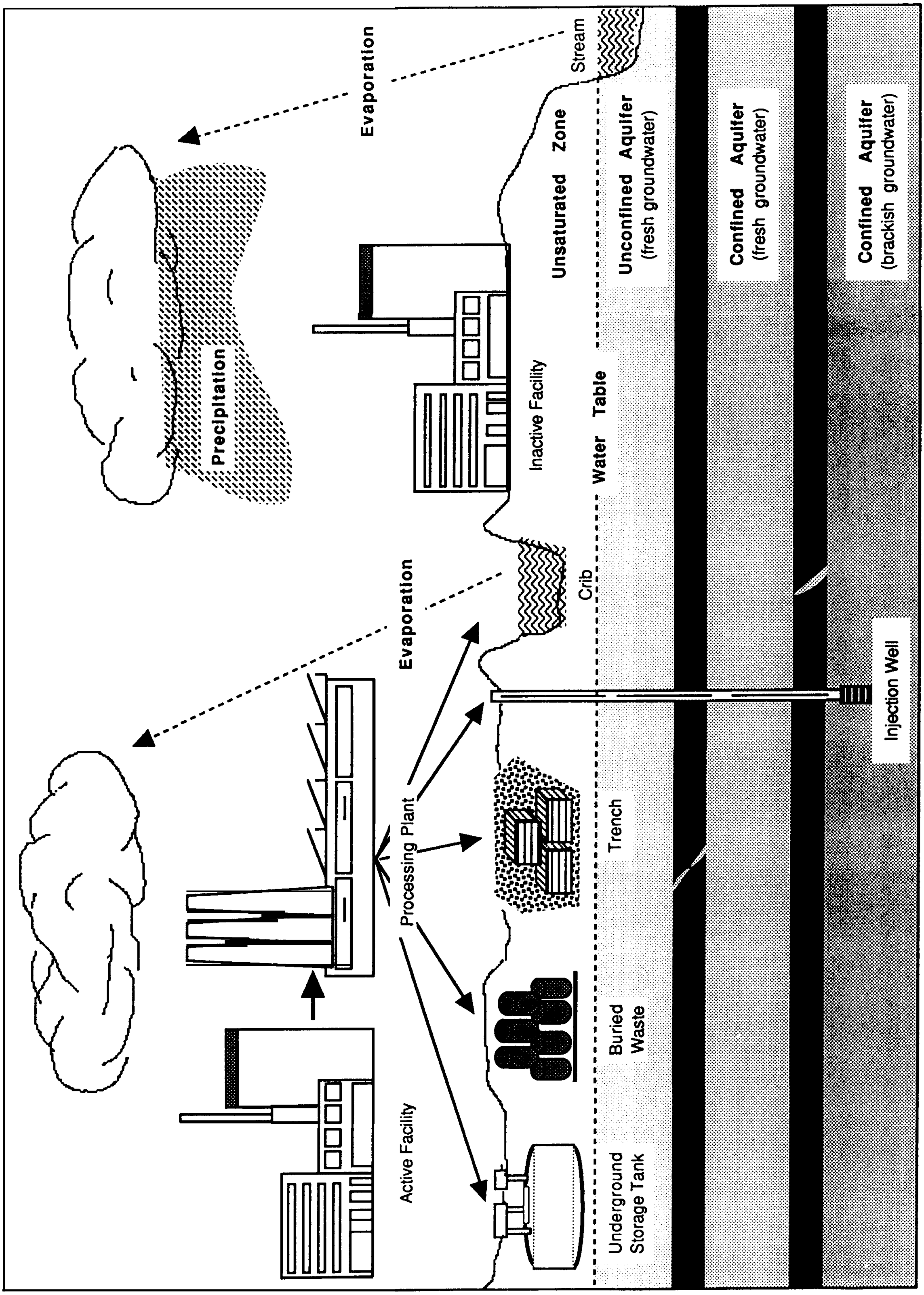
Contaminated soil and sediments of all categories are estimated to total billions of cubic meters. Table 2-1 shows the variety of radioactive and hazardous contaminants present at DOE sites. Appendix A identifies specific contaminants at each site. Figure 2-1 illustrates contaminant pathways into soil and groundwater, and table 2-2 lists the status of known centamination of soil, groundwater, surface water, and sediment at each of the sites. Appendix D discusses ecological issues related to this contamination.

Although these estimates of vast quantities of old buried waste; of contaminants in pits, ponds, and lagoons; and of the migration of contamination into water supplies serve to dramatize the problem, very little characterization of each site has been accomplished. DOE has stated that it is continuing to discover new problems.[3] Until characterization has been completed in accordance with applicable regulations—a process that OTA analysis shows will take about 5 years (see figure 2-2)-effective remediation measures cannot be initiated.

[2]Pub. L. No. 94580,90 Stat. 2795 (1976) (codified as amended at 42 U.S.C. §6901-07 (1982); 42 U.S.C. §§6911-16, 6921.31,694149,6951-54, 6961-64,6971-79,6981-86 (1982)); amended by Solid Waste Disposal Act Amendments of 1980, Pub. L. No. 96-482,94 Stat. 2334 (1980) (codified at 42 U.S.C. $6901-91(i) (1982)); Hazardous and Solid Waste Amendments of 1984, Pub. L. No. 98-616, 98 Stat, 3221, 3224 (codified at 4U.S.C. §6924 (1984)). Although RCRA referred only to the Amendments of 1980, the term is now used to include the Solid Waste Disposal Act of 1965 and its subsequent amendments. RCRA Section 1004(5) defines "hazardous waste" as any "solid waste or combination of solid wastes which, because of its quantity, concentration, or physical, chemical or infectious characteristics may (a) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible or incapacitating reversible illness; or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. " Pursuant to RCRA Section 3001, the Environmental Protection Agency has promulgated regulations that identify specific hazardous wastes, either by listing them or by identifying characteristics that render them hazardous.

[3]Secretary of Energy James D. Watkins, testimony at hearings before the Senate Committee on Energy and Natural Resources, May 2, 1990.

Figure 2-1—Examples of Groundwater Contamination Sources



SOURCE: Office of Technology Assessment, 1991.

Table 2-2—Known Contamination at Weapons Complex Facilities

Facility	Contamination On-site	Contamination Off-site	Limited corrective measures
Oak Ridge Reservation	S, GW, SW, Se	SW, Se	s, Sw
Pinellas Plant	GW		
Savannah River Site	S, GW, SW, Se	SW, Se	GW
Feed Materials Production Center (Fernald)	S, GW, SW, Se	GW, Se	S, GW, SW
Mound Plant	S, GW, SW, Se	GW, SW, Se	S, SW, Se
las Alamos National Laboratory	S, GW		
Pantex Plant	GW		
Sandia National Laboratory	S, GW		
Kansas City Plant	S, GW, Se	Se	S, GW, Se
Rooky Flats Plant	S, GW, SW, Se	SW, Se	GW
Lawrence Liverrnore National Latmratory	S, GW, Se	GW	S, GW
Nevada Test Site	S, GW		
Hanford Plant	S, GW, SW, Se	SW, Se	
Idaho National Engineering Laboratory	S, GW, Se	s	

NOTE: S = soil; GW = groundwater; SW= surface water; Se= sediment. Information on air contamination was not obtained.

SOURCE: Office of Technology Assessment, 1991; based on U.S. Department of Energy 1987-1988 Draft Environmental Survey; interviews with U.S. Environmental Protection Agency regional offices; DOE review letter from R.P. Whitfield to Peter Johnson, June 22, 1990.

Goals of Environmental Restoration

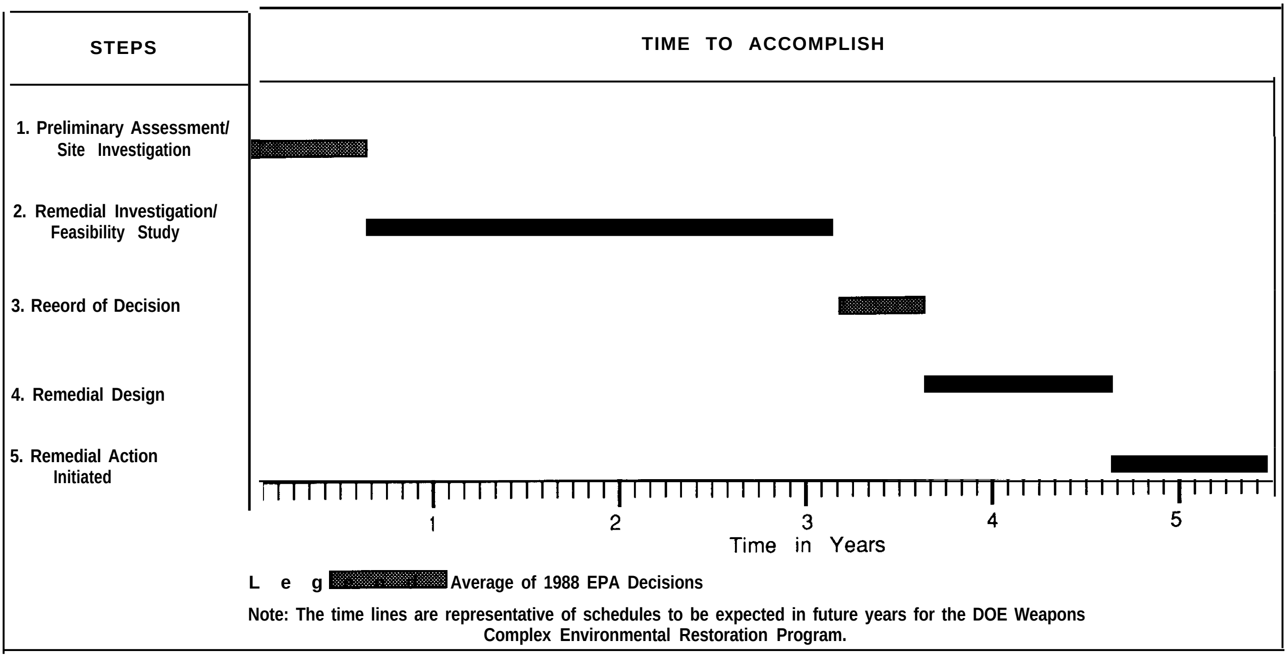
DOE has begun to face the enormous task of environmental restoration at sites within the Weapons Complex. Plans addressing the size, scope, time, and resources required have been developed only recently. The DOE Five-Year Plan describes its goals, strategies, and specific programs for assessment and cleanup of contaminated sites and facilities to meet standards prescribed in Federal and State laws. The first Five-Year Plan was issued in 1989 and covered FY 1991-95 (referred to hereafter as the 1989 Five-Year Plan) (l). The Five-Year Plan issued in 1990 updates the 1989 plan and covers FY 1992-96 (referred to hereafter as the 1990 Five-Year Plan) (4).

In the 1990 Five-Year Plan, DOE states that it is committed to the goal of environmental cleanup at all weapons sites by the year2019 and that the public must be involved in the process (6). According to DOE, "the 30-year goal for environmental restoration is to ensure that risks to the environment and to human health and safety posed by inactive and surplus facilities and sites are either eliminated or reduced to prescribed, safe levels" (7). This goal has been used by DOE in its planning documents for environmental cleanup at sites within the Nuclear Weapons Complex. Although the extent of cleanup has not been determined explicitly for each site, DOE has stated its intent that 'facilities and sites be returned to a condition suitable for unrestricted use. '

[4]DOE defines ''environmental restoration'' to include all ''remedial actions'' and "deCon lamination and decommissioning" at all DOE facilities. Remedial action encompasses: 1) site discovery, preliminaryassessment, and inspection; 2) site characterization, analysis of cleanup alternatives, and selection of a remedy; 3) cleanup and site closure; and 4) site compliance and monitoring. In this study, OTA uses "environmental restoration" to encompass remedial actions at the DOE Weapons Complex but does not include facilities that are not within the complex.

[5]DOE has also stated that ''in certain instances'' in situ stabilization and disposal may be the alternative selected. According to DOE, this will depend on: "l) specific site conditions; 2) the type, nature, extent, and amount of contaminantts present; 3) availability of suitable cleanup technologies; 4) regulatory factors; or 5) other agreed to (with regulators) considerations" (8).

Figure 2-2—Typical Schedules for Key Steps in the CERCLA Process From Beginning to End at the 'DOE-Weapons Complex



SOURCE: Office of Technology Assessment, 1991, with data from recent Superfund experience, 1989.

Regulatory Context of Environmental Restoration

DOE's environmental restoration activities must be conducted pursuant to applicable environmental laws. The principal environmental laws dictating how the cleanup is to be performed at the weapons sites are the Resource Conservation and Recovery Act, as amended (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act, as amended (CERCLA) (also known as Super-fund).[6] Recently, certain provisions of the National Environmental Policy Act,[7] as amended (NEPA), have also played an important role in the CERCLA-based cleanup process. DOE's environmental restoration efforts are also subject to State laws and regulations, including those set forth under the authority of RCRA and CERCLA (see box 2-A).

DOE nuclear weapons facilities are subject to RCRA requirements, including permits, reporting, and corrective action.[8] Weapons Complex sites must have RCRA permits-or qualify for "interim status" —to operate as treatment, storage, and disposal (TSD) facilities managing hazardous waste. In addition, they must address any release of hazardous material into the environment. Specifically, RCRA requires "corrective action" for the release of hazardous waste from both active and inactive units at a facility that is seeking a RCRA permit.[9] Thus, before issuing a permit for treatment, storage, or disposal of hazardous waste at a weapons facility, the Environmental Protection Agency (EPA) or an

6Pub. L. No, 96.510,94 Stat. 2767 (1980) (codified as amended in scattered sections of the I.R.C. and 33,42, and 49 U. S.C.). Throughout this report, any reference to CERCLA should be construed as a reference to the 1980 statute, as amended by the 1986 Superfund Amendments and Reauthorization Act and codified at 42 U. S.C.A. $$9601-11050 (West 1983 and Supp. 1990).

7Pub. L. No. 91-190, 83 Stat. 852 (1970) (codified as amended at 42 U. S.C.A. $$4321-47) (West 1983 and Supp. 1990).

8See RCRA section 6001; 42 U.S.C.A. §6961 (West 1983).

9RCRA Sections 3008(h), 3004(u) (on-site), and 3004(v) (off-site) specify corrective actions. RCRA Section 3004(u), enacted in the Hazardous and Solid Waste Amendments of 1984, prescribes that an Environmental Protection Agency (EPA) or State RCRA permit must require "corrective action for all releases of hazardous waste or constituents from any solid waste management unit [SWMU] at a treatment, storage, or disposal facility seeking a permit. . . regardless of the time at which waste was placed in such units. " Under this section, EPAmust also promulgate standards requiring corrective action for the release of hazardous waste from SWMUs at any TSD facility seeking a permit.

Box 2-A—Key Laws and Regulations Governing Cleanup at the Nuclear Weapons Complex

RCRA—The Resource Conservation and Recovery Act (RCRA) was enacted in 1976 to address the widespread contamination problem resulting from the disposal of municipal and industrial solid waste. Managed by the U.S. Environmental Protection Agency (EPA) or EPA-authorized States, the RCRA program focuses on reducing the generation of hazardous waste and conserving energy and natural resources. DOE's Nuclear Weapons Complex facilities are subject to RCRA and therefore must apply for an EPA or State permit to treat, store, or dispose of hazardous wastes or radioactive waste mixed with hazardous pollutants. Under the Hazardous and Solid Waste Amendments of 1984 (HWSA), DOE is also required to address and eliminate contaminant releases at or from its RCRA facilities within a schedule specified by EPA. This type of activity, called corrective action, is now being carried out at most weapons sites. Releases from inactive or abandoned sites or from accidental spills are not subject to RCRA, but they may be required to be remedied according to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

CERCLA—The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (also known as Superfund) provides the U.S. Environmental Protection Agency (EPA) with the authority to assess contaminant releases from abandoned waste sites (such as those within the Nuclear Weapons Complex), categorize sites according to their risks, and include them in the National Priorities List if EPA considers their cleanup a national priority. Both radioactive and hazardous contaminants are included under CERCLA authority. Table 2-3 indicates that eight of the Nuclear Weapons Complex sites are currently listed by EPA as requiring cleanup under CERCLA. The Superfund Amendments and Reauthorization Act (SARA) of 1986 authorize EPA to negotiate interagency agreements with other Federal agencies and States and to oversee Federal agency efforts toward developing appropriate remedies.

NEPA—The National Environmental Policy Act (NEPA) of 1970 mandates that all Federal agencies and departments take into consideration the adverse effects that their actions may have on the environment. The Council on Environmental Quality is responsible for developing the guidance for Federal agencies to comply with the act. NEPA requires that agency actions be reviewed early in the planning process and that the process be open to public participation. This review often results in the preparation of an Environmental Assessment or an Environmental Impact Statement (EIS), usually on a specific project. An EIS prepared for an entire program of agency activities is called a Programmatic EIS (PEIS). DOE is currently preparing a PEIS for its Five-Year Plan for waste management and environmental restoration and its modernization plan for the Nuclear Weapons Complex.

SOURCE: Office of Technology Assessment, 1991.

authorized State must require DOE to take such corrective action. If the corrective action cannot be completed before issuance of the permit—which is invariably the case at DOE weapons facilities—the RCRA permit must contain schedules of compliance for the corrective action.

Most of the DOE weapons facilities are operating under interim status.[10] EPA has authority under RCRA to require interim status facilities to take corrective action or other necessary response measures whenever it is determined that there is, or has been, a release of hazardous waste or constituents from a facility.[11] EPA is authorized to issue a corrective action order, which can suspend or revoke the authority to operate an interim status TSD facility, or to seek appropriate relief (including an injunction) from a U.S. district court. RCRA also authorizes EPA to require corrective action at and beyond the facility boundary and to issue civil and criminal actions to those unable to demonstrate compliance.[12] Because of EPA's limitations under RCRA in prosecuting other Federal agencies[13] and

[10]RCRA Section 3005(e) establishes the "interim status" provision for existing TSD facilities, which allows them to continue to operate while going through the final permitting process until a site-specific permit is issued. To obtain interim status, a DOE facility has to submit a brief preliminary application (called a "Part A Application") and comply with interim status requirements for waste management. It must then prepare and file a Part B application for a final permit. 42 U.S.C.A §6925(e) (West Supp. 1990).

[11]See RCRA Sections 3008(h), 3004(u), and 3004(v); 42 U.S.C.A. §§6924(u)-(v), 6928(h) (West Supp. 1990).

[12]See RCRA Section 3004(v); 42 U.S.C.A. §6924(v) (West Supp. 1990).

[13]U.S. Environmental Protection Agency, Office of Solid Waste, Permits and State Programs Division, and the Association of State and Territorial Solid Waste Management Officials, *RCRA Orientation Manual—1990 Edition* (Washington DC: U.S. Government Printing Office, 1990), p. III-90.

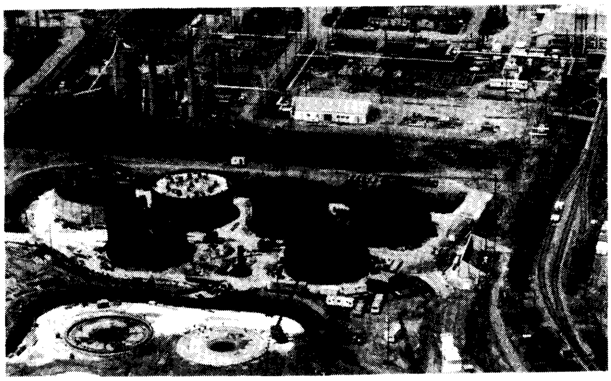


Photo credit: U.S. Department of Energy

Storage tanks for high-level waste under construction at Savannah River from 1980 to 1982.

the 1977 Memorandum of Understanding[14] making the Department of Justice solely responsible for conducting legal proceedings on behalf of EPA, EPA can only issue civil penalties in the form of fines for failure to comply with a corrective action order.

DOE weapons plants are also subject to CERCLA and, in particular, to the special requirements and deadlines for cleanup of Federal facilities contained in CERCLA's Section 120 enacted by Congress in the 1986 Superfund amendments.[15] More than half of the Weapons Complex sites (see table 2-3) have been placed on the National Priorities List (NPL) following application of EPA's Hazard Ranking System. Examples of these include the Idaho National Engineering Laboratory (INEL); the Hanford, Rocky Flats, and Mound Plants; the Feed Materials Production Center (FMPC, also referred to as Fernald); the Savannah River Site; the Oak Ridge Reservation; and Lawrence Livermore National Laboratory (LLNL). Within 6 months of being listed, facilities are mandated under CERCLA to identify both the extent of contamination and appropriate remedial measures and to report the results to EPA for review. This step in the cleanup process is known as the remedial investigation/feasibility study (RI/FS).[16] EPA has 180 days to approve the RI/FS or ask DOE for additional inforrnation.[17] If approved, DOE officials at these NPL facilities are required to enter an interagency agreement (IAG) with EPA for remedial action.[18]

EPA policy is to have the State join in the IAGs. Thus, these agreements are often signed by three parties: DOE, EPA, and the State in which the facility is located (9). IAGs, which are normally entered into at the RI/FS stage, must include at least a schedule for accomplishing the cleanup, arrangements for operation and maintenance of the site, and a review of the cleanup options considered and the remedy selected.[19] IAGs are enforceable against DOE facilities through citizens' suits; civil penalties may be imposed for failure or refusal of a facility to comply with an IAG.[20] Table 2-4 gives the status of these IAGs as well as other agreements, decrees, and consent orders for each facility.

After completion of the RI/FS, a record of decision (ROD) that outlines proposed remedial alternatives is prepared and made available to the public for input and comment before it is signed.[21] The ultimate remedy selected must ensure compliance with cleanup standards (including State environmental requirements and Federal standards or criteria) that are "applicable" or "relevant and appropriate' under the circumstances (known as ARAR

14Memorandum of Understanding on Civil Enforcement Between the Department of Justice and the Environmental Protection Agency—June 13, 1977, [Federal Laws] Environment Reporter(BNA) 41:2401.

15Superfund Amendments and Reauthorization Act, Pub. L. No. 99-499, 100 Stat. 1615 (1986) (codified in various sections of tie I.R.C. and 10,29, 33 and 42 U.S.C.)

1642 U. S.C.A. §9620(e)(1) (West Supp. 1990).

1742 U.S.C.A. $%20(e)(2) (West Supp. 1990).

1842 U. S.C.A. §§9620(e)(2)-(6) (West Supp. 1990).

19CERCLA Section 120(e)(4); 42 U. S.C.A. 36920(e)(4) (West Supp. 1990).

20CERCLA Section 122(d) 104(b); 42 U. S.C.A. §§9604(b), 9622(d) (West Supp. 1990).

21The ROD must contain remedial technologies developed and selected according to CERCLA Section 121 (42 U. S.C.A. §§9621(a)-(f) (West Supp. 1990).

Table 2-3-Environmental Restoration Program Status at the Nuclear Weapons Complex

	Oak Ridge Reservation	Pinellas Plant	Savannah River	Fernald	Mound Plant	Los Alamos	Pantex Plant	Sandia	Kansas City	Rocky Flats	Lawrence Livermore National Laboratory (Main)	Nevada Test Site	Hanford	INEL
National Priorities List	Yes	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes
RFA or PA/SI Complete[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RFI or RI work plan submitted	Yes	u	No	Yes	Yes	No	No	No	u	Yes	Yes	?	u	u
CMS or FS complete[c]	P	No	No	No	No	No	No	No	Yes	P	u	No	u	Yes
Remedial or corrective actions implemented	Limited	No	Limited	Limited	Limited	No	No	No	Limited	Limited	Limited	Limited	No	Limited
Risk-exposure assessment	Limited	No	Limited	Planned	Limited	Limited	No	No	No	Limited	Yes	No	No	Limited
Number of SWMUs identified to date	587		14	313	?	73	603	143	135	35	178	?	?	

NOTE: P = partial; U = underway; X = not under consideration; ? = no information.
[a]RFA = RCRA facility assessment; PA/SI = preliminary assessment/site investigation under CERCLA.
[b]RFI = RCRA facility investigation; RI = remedial investigation under CERCLA.
[c]CMS = corrective measures study under RCRA; FS = feasibility study under CERCLA.
[d]Limited risk-exposure assessment reflects work that does not necessarily meet CERCLA requirements.

SOURCE: Office of Technology Assessment, 1991; based on U.S. Department of Energy 1987-1988 Draft Environmental Survey; interviews with U.S. Environmental Protection Agency and U.S. Department of Energy review letter from R.P. Whitfield to Peter Johnson, June 22, 1990.

requirements[22]).[23] Cleanup is required by CERCLA Section 120(e) to begin no more than 15 months after completion of an RI/FS. EPA regional offices retain discretion over precise remedies to be applied on a site-specific level.

Most Weapons Complex sites are subject to both CERCLA and RCRA. Some sites, which have not been placed on the NPL, operate only under the regulatory jurisdiction of RCRA (i.e., Pantex, Los Alamos, Sandia, Pinellas, Kansas City). A major difference between the CERCLA and RCRA laws is that CERCLA coverage includes both hazardous and radioactive contamination, whereas RCRA and its corrective action provisions cover only hazardous waste and the hazardous portion of mixed waste. At sites subject only to RCRA authority, some radioactive materials and releases of radioactivity to the environment are regulated exclusively by DOE, subject to the Atomic Energy Act.[24] DOE has its own set of internal directives[25] (DOE orders) governing radioactive waste management and the limitations of radionuclide releases to the environment.

Regulation of the current process to characterize contaminated sites and to select and implement adequate remediation falls under the jurisdiction of EPA, the States, or both.[26] Over the past 5 years, DOE has gradually been required to acknowledge that cleanup of the Nuclear Weapons Complex is subject to regulation by EPA (or the States) to the extent that hazardous materials are involved or a site is placed on Superfund's NPL. Until 1984, DOE claimed that it was exempted from regulation under hazardous waste laws such as RCRA because of its Atomic Energy Act authority relating to national security and sovereign immunity from State regulation.[27] A 1984 Tennessee Federal court decision rejected this claim and ordered DOE to comply with all RCRA provisions.[28] It was not until 1987 that DOE clarified that the hazardous portion of mixed waste at its sites is also subject to RCRA.[29]

EPA's Office of Waste Programs Enforcement, within the Office of Solid Waste and Emergency Response, is responsible for ensuring compliance with RCRA and CERCLA requirements. The Federal Facilities Hazardous Waste Compliance Office at EPA headquarters attempts to assist EPA regions to reach and implement CERCLA interagency agreements at NPL sites and to ensure compliance with RCRA (9). EPA believes that most sites can be addressed comprehensively pursuant to an enforceable agreement under CERCLA Section 120.[30] EPA is using the mechanism of the three-party IAG with the State, EPA, and Federal facilities as signatories to resolve jurisdictional overlaps and disputes about which statute to use and whose jurisdiction takes precedence.[31]

Site Characterization Activities

Site characterization is conducted for the purpose of understanding the nature and extent of environmental contamination. It is also important in designing remediation measures and monitoring their effectiveness. The process is lengthy and technically challenging.

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[22]42 u. S.C.A. $6921(d) (West Supp. 1990).

[23]A recent commentary explains the ARAR concept as follows: "For sites on the NPL. . .[a]ll legally applicable, relevant, and appropriate requirements (ARARs) contained in State environmental laws that are more stringent than Federal ARARs must be applied to remedial actions at Federal sites. . . . [A]lthough EPA has set forth 'objective' criteria for defining ARARs in various agency guidance documents and rules, the ultimate selection of cleanup standards is highly discretionary and involves a determination by EPA of what requirements (including State laws) make sense for remedying the site.. . . In addition, Section 121(i) of CERCLA states that nothing infection 120 (dealing with Federal facilities) shall affect or impair the obligations of a Federal agency to comply with. . .(RCRA)" (10).

[24]42 U.S.C. §§2011-2296 (1982 and Supp. IV 1986).

[25]Under the authority of Section 161(i)(3) of the Atomic Energy Act [42 U.S.C.A. 2201(i)(3) (1982)], DOE issues internal directives or orders to assure the protection of workers, the general public, and the environment from hazardous and radioactive waste. DOE orders generally consist of broad requirements with limited criteria on how to demonstrate compliance and with considerable authority delegated to field offices.

[26]Most States are authorized t. run the RCRA base program, and some have now been granted authority under the Hazardous and Solid Waste Amendments to regulate mixed waste. As of May 10, 1990, the States witb mixed waste authorization relevant to DOE's Nuclear Weapons Complex were Colorado, Idaho, New Mexico, Ohio, South Carolina, Tennessee, Texas, and Washington.

[27]42 u. S.C.A. 552201 Q), 2018 (1982).

[28]*Legal Environmental Assistance Foundation* v. *Hodel*, 586 F. Supp. 1163 (E.D. Tenn. 1984).

[29]Radioactive Waste; Byproduct Material, 52 Fed. Reg. 15938, 15940 (1987) (codifed at 10 CFR §962).

[30]The National Priorities List for Uncontrolled Hazardous Waste Sites; Listing Policy for Federal facilities, 54 Fed. Reg. 10520, 10523 (1989).

[31]EPA officials have stated that the IAGs satisfy an NPL Federal facility's corrective action responsibilities under RCRA as well as the public participation requirements of both CERCLA and RCRA, with a RCRA permit perhaps later incorporating the IAG as appropriate (9).

Table 2-4-Federal and State Agreements, Decrees, or Consent Orders Relevant to DOE's Nuclear Weapons Complex Facilities

DOE facility	Parties[a]	Consent decree, consent order, or agreements	Date of signing	Goal
Fernald	DOE, EPA	Federal facility agreement (FFA)	July 1986 (being renegotiated)	Assure DOE compliance with CAA,[b] CWA,[b] RCRA, and CERCLA '
	DOE, EPA	Consent agreement	Under negotiation	CERCLA-based deanup of surface and groundwater sources and of waste storage areas
	DOE, State	Consent decree	December 1988	Address compliance with RCRA, CWA, and CERCLA
	DOE, State	Consent decree	December 1988	Enforce compliance with CAA requirements
Hanford	DOE, EPA, State	FFA and consent order (tri-party agreement)	May 1989	Ensure compliance with all environmental regulations and the establishment of an effective cleanup program that integrates NEPA, CERCLA, and RCRA
Idaho National Engineering Lab	DOE, EPA	Consent order and compliance agreement (COCA)	July 1987	Coordinate corrective actions to address contamination at the site
	DOE, State	FFA	May 1990	Oversee DOE'smonitoring and compliance program on air, surface water, and groundwater
	DOE, EPA, State	Interagency agreement (IAG)	Under negotiation	Integrate RCRA/CERCIA investigations and cleanup requirements
Kansas City Plant	DOE, EPA	3008(h) administrative order on consent agreement	June 1989	Address groundwater contamination
Lawrence Livermore National Laboratory	DOE, EPA, State	Federal facility agreement	November 1988	Coordinate cleanup activities of soil and groundwater under CERCIA
Los Alamos National Laboratory	DOE, State	Federal facility agreement	Under negotiation	Ensure DOE compliance with RCRA requirements
Mound Plant	DOE, EPA	Federal facility agreement and consent order	Under negotiation	Coordinate remedial activities required under CERCLA Section 120
	DOE, State	Consent order and compliance agreement	Under negotiation	Ensure DOE compliance with the State's RCRA program
Nevada Test Site	DOE, EPA, State	Interagency agreement	Under negotiation	Combine RCRA and CERCLA investigations and cleanup requirements
	DOE, State	Agreement in principle	Under negotiation	Coordinate current and future corrective actions needed at the site
Oak Ridge Reservation	DOE, EPA	Federal facility compliance agreement (FFCA)	Under negotiation	Coordinate the application of corrective measures at PCB-contaminated areas
	DOE, EPA, State	Tri-party interagency agreement	Under negotiation	Integrate RCRA- and CERCLA-based cleanup activities
	DOE, EPA, State	Memorandum of understanding	1983	Establish ways of mutual cooperation
Rocky Flats Plant	DOE, EPA, State	Federal facility compliance agreement	July 1986	Coordinate RCRA- and CERCIA-based activities
	DOE, State	Mutual cooperation agreement	June 1989	Increase the level of cooperation between DOE and the State and achieve compliance with State regulations
	DOE, EPA, State	Federal facility agreement and consent order	December 1989	Update 1986 FFCA and achieve a more effective integration of RCRA and CERCIA in cleaning up the site
Savannah River Site	DOE, State	Consent order	February 1989	Require DOE to comply with RCRA
	DOE, EPA	Consent order	July 1987	Require DOE to comply with RCRA
	DOE, State	Consent decree	May 1988	Require DOE to comply with RCRA
	DOE, EPA, State	Federal facility agreement	Under negotiation	Combine RCRA and CERCLA investigations and cleanup requirements

[a]Parties listed are DOE (U.S. Department of Energy), EPA (U.S. Environmental Protection Agency), State (the appropriate agency of the State in which the facility is located), and NRDC (Natural Resources Defense Council).
[b]Clean Air Act, 42 U.S.C.A. §§7401-7626 (West 1983 and Supp. 1990); Clean Water Act, 33 U.S.C.A. §§1251-1376 (West 1968 and Supp. 1990).

SOURCES: U.S. Department of Energy, "Envfronmental Restoration and Waste Management: Five Year Plan," DOE/S-0070, 1989; Office of Technology Assessment, 1991.

Photo credit: U.S. Department of Energy

Wood pallets, contaminated from transport of uranium products, await transport on a concrete pad at the Feed Materials Production Center (Fernald) for shipment to Oak Ridge.

DOE's Five-Year Plan for environmental restoration is devoted mainly to describing work to be done pursuant to RCRA or CERCLA. Environmental regulations and guidance promulgated by EPA (or the States) require extensive documentation and review of characterization efforts prior to the submission of detailed plans for cleanup. DOE is currently engaged in following the site characterization process prescribed by applicable environmental regulations. Many project milestones have been established for this work. In most cases, characterization of contamination will continue for 5 or more years, and decisions will then be made on remediation techniques and programs. However, although the process of identifying and characterizing contaminant problems is underway, it is difficult to determine how much has been done and how much remains to be done for the Weapons Complex as a whole.

OTA has collected data on the status of site characterization activities at DOE weapons facilities and has found that, in almost all cases, this work is in the initial site assessment stage (see app. A). All sites are currently performing environmental assessment work under one or more of the following: a RCRA order (issued by a court), a RCRA permit (issued by a State or EPA), or a CERCLA interagency agreement (either between DOE and EPA or among DOE, EPA, and the State). A number of sites have already negotiated (or are in the process of negotiating) interagency agreements within which DOE, EPA, and the States specify terms or conditions for applying current regulations, and set timetables (see table 2-4). The Hanford Federal Facility Agreement and Consent Order (signed in mid- 1989) was the first of these tri-party agreements completed (1 1). This agreement-among DOE, EPA, and the Washington State Department of

Box 2-B—Preliminary Site Status Summary: Radioactive Waste Management Complex (RWMC) at INEL, as of July 1990

Type of Site: Burial site for radioactive (low-level and transuranic) and mixed waste—solids and liquids—from 1952, generally in unlined trenches.

Contamination Problems: Contaminants have migrated into surrounding soil; floods have enhanced migration. Plutonium has been detected in a clay layer about 110 feet beneath the site. Hazardous contaminants have been measured in the groundwater that is about 600 feet beneath the site.

Characterization Status: Special survey programs have been going on since 1987 when an agreement was signed between DOE and EPA. A hazardous waste work plan was issued by DOE in December 1988. This site is one of the reasons INEL was placed on the National Priorities List by EPA in November 1989. Under the CERCLA process, investigations are underway and have been expanded to include radionuclide contamination. Modeling of migration flows is also underway. Much more characterization work is planned through 1995.

Characterization Techniques: Traditional, standard techniques are being used for groundwater and soils sampling and analyses and air monitoring. Computer modeling has been used to simulate migration of contaminants. Other advanced systems are under development.

Remediation Status: No remediation work has been started and none is planned through 1995.

Remediation Techniques: The complex nature of the buried waste is expected to require a combination of remediation techniques. Three major technology demonstration projects are underway for buried waste and contaminated soils at the RWMC. These are in situ vitrification, vacuum vapor extraction, and buried waste retrieval. Other technologies being investigated include soil freezing as a pretreatment for retrieval, plasma furnace for destruction of organics, and solidification of inorganic contaminants into a vitrified waste form, soil washing for removal of transuranic contamination, and bioremediation treatment for destruction of organics and isolation of heavy metals.

Comments: Characterization work is proceeding at a slow pace and is probably limited by funding. Investigation and testing of more conventional stabilization and containment techniques could be pursued more aggressively.

SOURCE: Office of Technology Assessment, with U.S. Department of Energy data and review.

Ecology—covers both RCRA and CERCLA actions and discusses the activities subject to each. It also includes an action plan and milestones for major items of disposal, cleanup, and related paperwork.

Characterization of contamination problems involves three major elements: 1) detecting the presence of contaminants, 2) understanding their movement and changes after entering the environment, and 3) predicting their subsequent transport and fate (i.e., understanding what they are, where they are and in what concentration, how they are changing, and where they are going and how fast). Data requirements depend on the objectives of cleanup, the specific site, and the remedial technologies to be considered. As shown in table 2-3, DOE is just beginning to address the first of many steps in the characterization process—i.e., attempting to determine what releases have occurred and the location, type, and quantity of contaminants.

Current technical approaches to characterization are illustrated by activities at the following locations in three DOE facilities:

1. the Radioactive Waste Management Complex at INEL (see box 2-B),
2. Solid Waste Storage Area 6 at Oak Ridge (see box 2-C), and
3. the Feed Materials Production Center in Fernald, OH (see box 2-D).

All three sites are in the characterization phase; little or no remedial action has been initiated. At each site, only conventional techniques (well drilling, chemical or radioactive analysis of samples, etc.) are currently being used even though DOE is funding research into more advanced technologies (e.g., remote sensors).

Remediation Activities

Because very few contaminated sites in the Weapons Complex have reached the stage at which

Box 2-C—Preliminary Site Status Summary: Solid Waste Storage Area 6 at Oak Ridge National Laboratory, as of July 1990

Type of Site: Below- and above-ground storage of solid radioactive (primarily low-level, but one buried cask of transuranic waste), hazardous, and mixed (including inorganic, organic, and biological) waste, in trenches; silos; above-ground tumulus; unlined, capped auger holes; and landfill.

Contamination Problems: Disintegrating containers and the influx of water into trenches have led to the presence of tritium, cesium-137, and hazardous pollutants in trench leachate and to the migration of contaminants into groundwater (tritium, strontium-90, and hazardous pollutants).

Characterization Status: Standard surveys (under a RCRA facility investigation) have been underway since 1988. Other characterization work is planned.

Characterization Techniques: Characterization of contamination has been conducted by ground survey (walkover, dose rate, and electromagnetic terrain conductivity), gas and soil sampling, sediment sampling, surface and groundwater sampling, data analysis, and modeling.

Remediation Status: In 1976, a bentonite cover was used to seal one trench. However, water has been observed in underlying trenches. A French drain was installed in the trench area to prevent lateral movement of groundwater into it. Interim corrective measures have been undertaken: trenches with RCRA-regulated waste were covered with a high-density polyethylene cap.

Remediation Techniques: These are expected to include capping, surface water control, drainage upgrade; vertical barriers or French drains to lower the groundwater table; and possible groundwater extraction and treatment. Trench grouting and dynamic compaction have been demonstrated on a pilot scale.

Comments: Characterization work has used conventional, rather than advanced, techniques. Remediation technologies are still in the process of being selected.

SOURCE: Office of Technology Assessment, with U.S. Department of Energy data and review.

the amount, type, and extent of contamination have been characterized, little remediation has been proposed or carried out. OTA found that remediation activities have begun at only a few sites and are complete at hardly any. An example of a completed remediation activity is the S-3 Pond project at the Y-12 Plant in Oak Ridge. There the sludge in a series of old radioactive and hazardous waste storage ponds was stabilized through treatment and the addition of rock fill; an engineered cap was then installed. Box 2-E describes the project in more detail.

Several groundwater remecliation projects are underway, all involving 'pump and treat' techniques. Examples of such projects are air stripping organics from a large contaminated aquifer at Savannah River, ultraviolet light and ozonation treatment of a contaminated plume at the Kansas City Plant, ultraviolet light and hydrogen peroxide treatment of contaminants at the Lawrence Livermore National Laboratory, and pumping contaminated groundwater to a wastewater treatment plant at Femald. At other sites (i.e., Rocky Flats), simple collection systems such as French drains have been installed to intercept contaminated water and recycle it to a solar evaporation pond.

As seen from these examples, remediation activities at the weapons sites involve mainly conventional methods such as stabilizing soil or sediments by excavation or by treatment and installation of barriers or caps to prevent leaching. At the S-3 Ponds, investigations of more advanced methods such as in situ vitrification and grouting were carried out, but the techniques were rejected because of uncertain effectiveness, and conventional techniques were used instead. Similarly, in the remediation of contaminated groundwater, recent experience has also favored conventional pump and treat measures because other techniques (e.g., in situ bioremediation) have not been tested or their use is not considered appropriate. However, some newer technologies are being used in the treatment phase, and new technologies are being developed and tested at Savannah River to operate in conjunction with conventional pump and treat systems; these include in situ air stripping with horizontal wells.

Also, in most cases, remediation efforts at the Weapons Complex are considered "interim" in

Box 2-D—Preliminary Site Status Summary: Fernald, as of July 1990

Type of Site: Production facility for purified uranium metals and compounds. Used for storage and disposal of a variety of radioactive (uranium, radium, and thorium) and potentially hazardous chemicals (heavy metals, fluorides, asbestos).

Contamination Problems: Contamination of soil, surface water, sediment, and groundwater. Sources include airborne contamination from stacks, vents, and landfill; wastewater (process and sanitary waste); and leaking storage facilities (radioactive and hazardous chemicals). Potential for air release of radioactive materials stored on-site in silos.

Characterization Status: Ongoing groundwater monitoring; routine environmental monitoring; special studies (1976, 1985-87) commissioned of groundwater, waste pits (radar and electromagnetic terrain conductivity), and surface radioactive contamination. Sitewide remedial investigation/feasibility study underway, including waste characterization (since 1989).

Characterization Techniques: Sampling of soil, surface water and sediment, and groundwater by using DOE and EPA protocols; also groundwater modeling and waste inventory sampling by using EPA protocols.

Remediation Status: Four interim cleanup actions have been initiated: 1) containment of south groundwater contamination plume (above-background uranium concentration in groundwater), 2) pumping and treating perched groundwater beneath the production plant, 3) collection and treatment of stormwater runoff, 4) attenuation of radon emissions from the K-65 silos.

Remediation Techniques: Possible future use of in situ stabilization (vitrification or cementation); removal, treatment, and return or disposal of mixed waste; channel remediation (lining channels, excavating contaminated soil, diverting flow of surface water); groundwater pumping and treatment by using ion exchange, reverse osmosis, or precipitation.

Comments: The facility is well into its characterization program, and remediation technologies are undergoing evaluation. Several EPA Superfund Innovative Technology Evaluation programs might be effective in removing metals and mixed waste, including organic contaminants, from soil, pits, sediment, and groundwater.

SOURCE: Office of Technology Assessment, with U.S. Department of Energy data and review.

nature-i. e., containment measures to slow the migration and avoid further spread of' contaminants or to remove some contaminants, rather than to achieve permanent cleanup. Any 'permanent" cleanup actions have usually involved removing contaminated materials from a site and either storing them in containers or shipping them to another site. Such removals have occurred at Oak Ridge, Fernald, Rocky Flats, and the Mound Plant. Most of the shipments have been to the Nevada Test Site.

Throughout the Weapons Complex, DOE is faced with an enormous number of site remediation problems. Choices of effective and predictable cleanup techniques are extremely limited, however, because only a few approaches have been tested. Even conventional techniques are not always predictable when applied to specific sites. Widespread problems such as groundwater contamination are particularly intractable, as shown in box 2-F. DOE has advocated more testing of containment technologies, as well as research into approaches that have the potential to destroy some contaminants in place. Technology development is part of the Five-Yew Plan and is considered vital to ensure that future cleanup actions effectively meet DOE's long-term goals.

Evaluation of Present Efforts

Meeting Stated Goals

DOE's stated goal of environmental cleanup by the year 2019 represents a formidable challenge, and currently available information does not clearly demonstrate that it can be attained. Although it may be desirable for DOE to set a completion date on which to focus its activities, three major barriers stand in the way of achieving this goal: 1) decisions on cleanup levels and standards that can clarify DOE goals have not yet been established; 2) personnel qualified to conduct characterization and remediation at DOE sites are scarce; and 3) technologies for addressing some of DOE's more perplexing environmental problems are not currently available.

Box 2-E—Preliminary Site Status Summary: S-3 Ponds at Y-12 Plant, Oak Ridge Reservation, as of July 1990

Type of Site: Storage ponds for liquid radioactive (uranium and transuranic) and mixed (heavy metal, organic, and nitrate) waste.

Contamination Problems: Surface and groundwater contamination with heavy metals, volatile organics, and nitrates.

Characterization Status: Characterization completed.

Characterization Techniques: Conventional surface and groundwater monitoring.

Remediation Status: A RCRA final closure is completed and awaiting certification.

Remediation Techniques: 1) neutralization (1983-86) and denitrification of pond contents (1983-84); 2) effluent treatment and release (1983-86); 3) stabilization of sludge, rock fill, and engineered capping.

Comments: Denitrification as conducted here was precedent setting because of its use in open air and at high nitrate concentration. Effluent, after treatment, more than satisfied both EPA and State (Tennessee) requirements. The sludge was stabilized with only rock and soil fill (rather than by in situ vitrification or grouting) because of the desire to "get on" with remediation; these other technologies are still in the developmental stage. The area has been covered with asphalt for a parking facility. Groundwater will continue to be monitored to determine how effective these measures were and to determine whether future treatment is needed.

SOURCE: Office of Technology Assessment, with U.S. Department of Energy data and review.

The 1989 Five-Year Plan states that DOE will "contain known contamination at inactive sites and vigorously assess the uncertain nature and extent of contamination at other sites to enable realistic planning, scheduling and budgeting for cleanup" (12). During this start-up period for environmental restoration of the Weapons Complex, the unpredictable pace and quality of site characterization and the uncertainty of funding may hinder the attainment of even these short-term goals.

Given the potentially high cost of environmental restoration, the availability of funds over the entire 30-year cleanup is likely to be an issue. DOE agreements with EPA and the States contain various environmental restoration plans and milestones; the other signatories undoubtedly expect DOE to obtain the funding necessary to meet those commitments. However, the budgetary process does not ensure that this funding will be available; other entities beyond DOE's purview have responsibilities in this area as well. An important issue in this regard is whether and how interagency agreement provisions can be enforced if appropriated funds are insufficient to meet the milestones and schedules specified in the agreements.

Although DOE has set a 30-year cleanup goal, it has not prepared a long-range planning document with cost estimates to meet that goal. The absence of a budgeted plan can make the attainment of any goals difficult to achieve. Not since 1988, when DOE prepared a "needs assessment" report that attempted to describe environmental restoration requirements over a 20-year period, has this long-range view been addressed (13). Over 20 years, some projects could be planned to completion. The current DOE approach was initiated with the 1989 Five-Year Plan, which does not project beyond its limited time frame. Within that period, no DOE projects can be planned to completion.

DOE cites the uncertainties associated with environmental contamination problems at the Weapons Complex as justification for its use of a short-term planning horizon. Long-range planning and the estimation of total cost to completion will remain difficult until the sites have been characterized fully. Also, the levels of cleanup that will be technically feasible, required under applicable statutes and regulations (some of which are yet to be promulgated), or deemed acceptable to the regulators and protective of public health and the environment are not yet clear. Many of these uncertainties can be resolved only through experience. Other long-term projects with high degrees of uncertainty have been known to experience significant cost overruns and delays.

Box 2-F-Contaminated Groundwiater Can Be Difficult To Clean Up

Groundwater can become conaminated from numerous sources. At the Nuclear Weapons Complex, sources include accidents and spills; intentional introduction of waste into the ground (cribs, surface impoundments, underground injection wells, landfills); and failure of containment methods (underground storage tanks).

Groundwater contamination is very site-specific in terms of the contaminants present and their behavior. Groundwater contamination is such a difficult problem to characterize and cleanup because the environment is not uniform. In genenral, the less uniform the environment (such as fractured limestone at Oak Ridge or the presence of clay lenses at Savannah River), the more difficult it is to characterize contamination problems and clean them up. Some contaminants will be easier to find and clean Up than others. For example, those contaminants that move with water are easier to find than those that do not.

Contaminants at the Weapons Complex include radionuclides, heavy metals, nitrates, and organic contaminants (see table 2-1). Often these are present as complex mixtures that affect the mobility and fate of individual contaminants in the subsurface. Contaminants also behave in different ways, depending on the characteristics of a site. As contaminants move through the ground to an aquifer, many processes occur that affect the amount or concentration of the contamination by the time it reaches a receptor of corlcem such as a well or surface water. The processes may also affect the performance of remediation techniques. Many of these processes, however, are not well understood.

Some contaminants adsorb onto soil particles in the unsaturated zone or onto the aquifer media, thereby slowing their movement and possibly preventing groundwater contamination. Contaminants may also form or adsorb onto colloidal particles, which allows them to move with, or faster than, the average groundwater flow. Flow can result from an apparently unrelated force, such as the flow of water and contaminants due to a thermal or electrical gradient instead of the expected hydraulic gradient. Chemical reactions and biotransformation may occur, possibly changing the toxicity or mobility of contaminants. Some contaminants dissolve and move with the water; some are in the gas phase; others are nonaqueous phase liquids; some are more dense than water and may move in a direction different from groundwater others may be less dense than water and float on top of it.

Contaminants that dissolve in water can often be extracted from groundwater and cleaned up with pump and treat techniques. This is the most commonly used procedure to clean up contaminated groundwater. Pump and treat can successfully remove great quantities of contaminants; however, the approach often takes much longer than originally planned to reduce contaminants to desired levels. Pumping can often bean effective way to prevent the spread of groundwater contamination and even reduce the size of a contaminated plume, but in some cases it may not be possible to restore aquifers by pump and treat methods. EPA recognizes that, with current technologies, complete groundwater restoration may not be practicable in some circumstances, such as highly contaminated zones near the source of contamination that remain contaminated at levels preventing beneficial use. Imng-term containment, natural attenuation, wellhead treatment or alternate water supply, and institutional controls to restrict water use may be necessary rather than attempting to restore an aquifer to health-based standards.

Because contaminated groundwater is so difficult to clean up, it is especially important to prevent contamination from occurring in the first place and to prevent it from spreading further once it has occurred.

SOURCE: **Office of Technology Assessment, 1991.**

Site Characterization

Characterization— the process of locating, identifying, and evaluating huge quantities of radioactive and hazardous wastes that have migrated through the subsurface-is technically complex, costly, and loaded with uncertainty. It currently involves drilling hundreds of wells, collecting and analyzing samples, modeling contarninant migration, and other activities. Characterization is a difficult task that requires a high level of expertise to implement properly. The quality of' characterization can be harmed by poor planning, inappropriate methods, or incorrect field and laboratory procedures. Even the best approaches may yield highly uncertain results about fate and transport. This uncertainty is a particular problem for certain types of contaminants found at DOE weapons sites and for certain hydrogeologic environments.

As an example, although groundwater contamination may be identified from a few samples, understanding the concentration, extent, and movement of that contamination requires much more extensive

Photo credit: Martin Marietta Energy Systems

S-3 Liquid Waste Holding Ponds at the Oak Ridge Y-12 Plant. The photo on the left shows the pond before remedial action was taken. More than 10 million gallons of liquid waste were treated from the four 1-acre ponds. Sediment in the empty pond basins was stabilized with 60,000 tons of gravel, followed by a covering of 15,000 cubic yards of clay and additional layers of sand and topsoil. The ponds have been paved and are being used as a parking lot as shown by the photo on the right of the S 3 Ponds afterpaviing.

sampling; even then, only partial information will be gathered (see app. B). In addition, great technical uncertainty is inherent in predicting the fate and transport of contaminants. In many instances, characterization work has been underway for several years but has not produced sufficient data to determin e the risks of contamination reaching human receptors (see ch. 3). Throughout the characterization process, therefore, DOE'S efforts must involve careful assessment of risks and must be subject to long-term monitoring to ensure that urgent problems are identified and receive immediate remedial attention.

Although sufficient characterization must be accomplished before intelligent cleanup decisions can be made, it is wasteful and sometimes risky to insist on characterizing every situation completely before any cleanup is begun. Achieving a balance between sufficient understanding and cleanup action requires the collective judgment of professionals from many disciplines. As characterization proceeds, however, it is becoming evident that people qualified to conduct and oversee characterization are kicking both at DOE sites and at Federal, regional, or State regulatory agencies. This problem may further lengthen the characterization process, lead to delays in commencing remediatition, and result in new problems in the future. DOE has recognized the need for qualified personnel and must now focus adequate attention on building this cadre of professionals.

Site Remediation

Few remediation techniques are available to DOE for cleanup of many contamination problems at the weapons sites (e.g., groundwater, buried waste, pits, ponds, lagoons, soil, sediments). Those available are limited mainly to capping and stabilizing soil (e.g., at the old settlement ponds at Oak Ridge or Hanford); pumping and treating groundwater (e.g., at LLNL, Savannah River, or Kansas City); and excavating and storing mixed waste (e.g., at Oak Ridge and Rocky Flats). These techniques are used because they have been tested enough to receive regulatory approval. Regulatory approval implies that the consequences of their use are known, but much more work is required to test and prove the effectiveness of these techniques at the Weapons Complex.

OTA has examined the prospects and limitations of various approaches to environmental restoration of some the problem areas found at the Weapons Complex (see app. B). For example, groundwater remediation, in many instances, may prevent the spread of contamination but does not completely remove contaminants from the environment. Pump and treat systems have been tested at Savannah River, LLNL, Kansas City, and elsewhere for the control of organic chemicals in groundwater. These types of contamination may be contained in the future but they probably cannot be eliminated completely. Although newer treatment technologies such as bioremediation are promising, they have not been proved and also have limitations regarding either the extent of cleanup possible or the time required. In light of these limitations in cleanup capabilities over most of the next 30 years, DOE should develop plans for continuous monitoring of groundwater contamination over long periods to ascertain the effectiveness of containment by available technologies.

For contaminated soil or buried waste, it is not clear whether removal and destruction of some contaminants on-site (e.g., through incineration) or removal and disposal elsewhere offer greater benefits. Some disadvantages of the removal option include worker health risks and the likelihood of increased air emissions when incineration is used. A possible disadvantage of the in situ approach is partial destruction of the toxic elements (in the case of mixed waste). If the disadvantages of waste removal are fairly significant, the alternative of leaving waste or contamination in place and stabilizing it may be the most prudent approach. However, DOE has not analyzed these options carefully enough in specific cases and has not evaluated possible alternatives. The cases requiring evaluation are many and varied and could require different solutions.

What "cleanup" really means may not become evident to the public until actual decisions on remediation techniques are made. In many instances, certain waste and contamination now present at DOE weapons sites—for one reason or another, and in some form or another-will probably remain there considerably beyond the year 2019. Certain situations throughout the Weapons Complex are particularly troublesome, and no reasonable technical solutions are currently available. Among these are centaminated soil at Hanford (from old crib discharges),[32] plutonium-contaminated soil at Rocky Flats, buried transuranic waste at INEL, high-level waste injected into the subsurface at Oak Ridge, uranium-contaminated soil at Fernald, and the single-shell tanks at Hanford. For example, the situation with respect to these single-shell tanks should be carefully assessed to determine the risk to workers and the community from excess radiation exposure. If the waste is to be removed and relocated, this risk should be compared with the risk of alternative solutions.

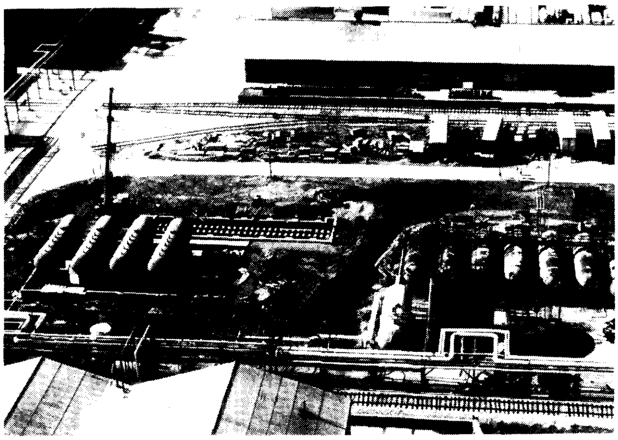


Photo credit: U.S. Department of Energy

Hazardous chemicals used in various Fernald processes are stored in a centralized tank farm, which contains original equipment installed in the 1950s. A comprehensive safety review, completed in 1985, recommended both short- and long-term improvements in storage. All near-term improvements are now complete.

The Nation must begin to define the extent of cleanup that is possible and practical, to identify the decisions that must be made about long-term stabilization and monitoring, and to initiate a process that will specify scientifically sound and publicly acceptable cleanup standards. Considerable confusion and ambiguity surround the cleanup standards that DOE will be required to meet. Box 2-G illustrates three situations contributing to this confusion: 1) radiation protection guidance is outdated; 2) CERCLA cleanup standards are at least 5 years from being finalized; and 3) no maximum concentration level standards have been set for radon or uranium in drinking water. These problems and others should receive high priority.

DOE is now emphasizing the development of new technologies that may be more effective, be less costly, and go farther toward actual destruction of some contaminants (14). New technologies may offer benefits for treating certain types of waste or contamination in place (in situ), but they generally require much more testing and evaluation than are currently planned. In addition, many of these technologies, especially those using biological processes, work very slowly and their progress is difficult to monitor. Thus, they probably cannot be applied to weapons sites until determinations are made about required or acceptable levels of cleanup

[32] Cribs are shallow trenches dug in the ground and used to receive overflow from the old high-level radioactive waste tanks.

Box 2-G—Examples of Cleanup Standards Needing Attention

Radiation Protection Standards

The existing Federal guidance for protection of the public against radiation is outdated, and the development of new guidance is uncertain.

In developing regulations to protect the general public against radiation, EPA adopted the Federal guidance developed by the now-defunct Federal Radiation Council and approved by President Eisenhower in 1960.[1] With the exception of the radiation protection standards issued by EPA in 1979 to control radionuclide emissions from nuclear power plants, relatively little has been done in this area under the authority of the Atomic Energy Act. As a consequence of this deficiency, Federal agencies (e.g., DOE and the Nuclear Regulatory Commission) promulgate agencywide orders requiring compliance with radiation limits they believe will protect the public. Most of these standards, however, are derived from permissible radiation levels for occupational exposure. In an effort to update the Federal guidance for public protection, EPA has formed an interagency group called "the Residuals Project" to make suggestions for updating the guidance within a few years. It is uncertain when and whether EPA would revise their standards to reflect: 1) recent findings by the National Research Council's Committee on Biological Effects of Ionizing Radiations[2] (BEIR V report) that the risks of low-level ionizing radiation are two to three times more serious than it previously anticipated and 2) the draft recommendation by the International Commission on Radiological Protection that the current radiation limit for workers be reduced by 60 percent.

Site Cleanup Standards

CERCLA requires EPA to develop cleanup standards for radioactively contaminated sites; however, cleanup standards are at least 5 years away from being finalized.

EPA is planning to develop standards for the cleanup of radicactively contaminated sites. This task will be conducted by Residuals Project members after completion of their work on radiation protection. Standards will address radioactive contamination not covered by high-level, low-level, or media-specific regulations. EPA expects to promulgate its final cleanup standards in 5 to 10 years. These will be needed for much of the large-scale cleanup contemplated at the Nuclear Weapons Complex.

Drinking Water Standards

Current primary drinking water standards do not provide maximum concentation levels (MCLs) for radon or uranium contamination. EPA is attempting to address this need; however, no appropriate standards for protection of drinking water from these radionuclides are expected to be proposed before 1992.

Section 1412 of the Safe Drinking Water Act[3] (SDWA) requires EPA to issue primary standards to control the amounts of radionuclides in public drinking water systems. As opposed to the "radiation dosage" approach (i.e., allowed dose to the maximally exposed individual) used by the Office of Radiation Programs for developing radiation protection standards, the Office of Water uses the "population dose" concept (i.e., MCLs) to develop drinking water standards. The primary objective of the MCLs currently enforced is to prevent the contamination of groundwater sources by manmade radiation, particularly radium-226, radium-228, and gross alpha particle activity.

At present, the drinking water quality standards are being revised. The most relevant options being considered by the Office of Water are: 1) modifying the current standard to include separate MCLs for radium-226 and radium-228, 2) proposing MCLs for radon and uranium, 3) using the current gross alpha particle activity standard for monitoring purposes, and 4) replacing the concentration levels for radionuclides with a single limit for all radionuclides.

Uncertainties associated with their occurrence, toxicity, and exposure routes have prevented EPA from promulgating maximum concentration levels for radon and uranium. EPA expects to issue its revised standards in early 1992.

[1]Federal Radiation Council, Radiation Protection Guidance for Federal agencies, 25 Fed. Reg. 4402 (1960).

[2]National Research Council, Committee on the Biological Effects of Ionizing Radiations, *Health Effects of Exposure to Low Levels of Ionizing Radiation—BEIR V* (Washington, DC: National Academy Press, 1990).

[3]42 U.S.C.A. § 300g-1 (West 1982, and Supp. 1983-1989).

SOURCE: Office of Technology Assessment and footnotes 1, 2, and 3.

Box 2-H—Types of Waste

High-Level Waste (HLW): The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation.

Transuranic (TRU) Waste: Without regard to source or form, waste that is contaminated with alpha-emitting transuranium nuclides with half-lives longer than 20 years and concentrations higher than 100 nanocuries per gram at the time of assay.

Low-Level Waste (LLW): Waste that contains radioactivity and is not classified as high-level waste, transuranic waste, spent nuclear fuel, or byproduct material. Test specimens of fissionable material irradiated for research and development only, and not for the production of power or plutonium, may be classified as low-level waste, provided the concentration of transuranics is lower than 100 nanocuries per gram.

Hazardous Waste: Waste that is designated hazardous under RCRA and EPA regulations.

Mixed Waste: Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively.

SOURCE: U.S. Department of Energy Order No. 5820.2A.

over extended periods. In the past, only a few remediation technologies received sufficient long-term developmental attention and funding to bring them to the point at which they could be applied to actual cleanup projects.

If benefits are to be achieved from new technologies, future DOE technological development programs will have to focus more carefully on major remediation needs and will require a consistent long-term coremitment of resources. Yet, although the promise of new techniques for remediation is real, technological research is only part of what is required to develop them. An entire program must be implemented that will develop, test, and implement these techniques, as well as obtain regulatory and public approval for their use.

WASTE MANAGEMENT

Status

Overview

Environmental problems at the Nuclear Weapons Complex today are a direct result of poor waste management practices over the past 40 years. The challenge now facing DOE is how to design and build a waste management system that will prevent future contamination from radioactive and hazardous materials. Waste management has been given attention in recent years by DOE, and major funds (about $1.5 billion in FY 1991) are now directed toward waste management projects throughout the Weapons Complex.[33] DOE has acknowledged, however, that much more needs to be done especially in minimizing future waste generation, building treatment systems to create more secure forms of waste, and creating better and safer long-term storage and disposal facilities.

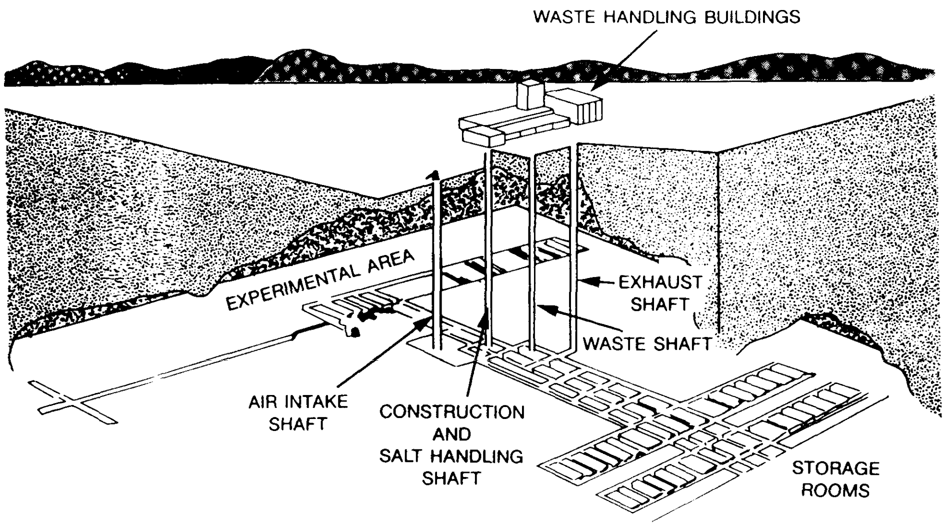
In the 1990 Five-Year Plan, almost two-thirds of current and future funding is devoted to waste operations.[34] This funding initiative reflects the fact that, although major waste management facilities are now under construction, most DOE waste is still stored at all sites under temporary, sometimes marginal, conditions. Making the transition from temporary storage to safer, more permanent conditions will require major investments.

Since the 1970s, DOE has organized its waste management programs by type of waste and thus has had separate programs for the storage and disposal of high-level waste (HLW), transuranic (TRU) waste, and low-level waste (LLW) (see box 2-H). In addition, DOE is required to manage hazardous

[33] In this assessment, OTA has focused on the evaluation of high-level and transuranic waste management at the Weapons Complex because these forms pose the most risk, they are unique to DOE, and the bulk of current and future resources will be devoted to them. For a discussion of low-level and mixed waste primarily in the commercial sector, see the 1989 OTA report "Partnerships Under Pressure: Managing Commercial Low-Level Radioactive Waste" (15).

[34] Unlike environmental restoration, a relatively new concept at the DOE Weapons Complex, waste management has been a traditional function for a long time. It has always been necessary, as part of weapons production, to control and dispose of generated waste products.

Figure 2-3—The Waste Isolation Pilot Plant: Its Capacity, Estimated Operational Cost, and Estimated Lifetime



Total waste capacity:	6 million cubic feet
Current accumulated waste volume:	2.12 million cubic feet
Construction cost to date:	$700 million
Estimated cost for 25-year operation:	$2.5 billion
Estimated total time to fill the WIPP repository:	20 - 30 years

SOURCE: Office of Technology Assessment and U.S. Department of Energy.

waste and mixed waste in accordance with EPA and State regulations. The 1990 Five-Year Plan discusses DOE programs for managing the waste at the Weapons Complex and reflects the recent reorganization of DOE waste management activities. Programs for treating, storing, and disposing of the weapons waste are now the province of the Office of Waste Operations, one of three subdivisions of the Office of Environmental Restoration and Waste Management.

According to current DOE plans, most of the high-level and transuranic waste now stored at various weapons sites would be shipped off-site for disposal to two repositories-one for each type of waste. Congress has mandated that a site at Yucca Mountain, NV, be evaluated for potential use as a deep geologic repository for both commercial spent fuel and high-level waste from the weapons plants. High-level 'waste would be placed there-if and when the site proved suitable (16). In 1980, Congress authorized the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM, as a research and development facility to demonstrate the safe disposal of radioactive waste from U.S. defense activities and programs.[35] DOE now plans to conduct tests at this facility (see figure 2-3) and, if it is deemed suitable, to dispose of retrievable stored and yet-to-be-generated TRU waste from the weapons sites there (16).

Most high-level waste at the weapons sites is currently stored in liquid or semiliquid form in underground tanks (see box 2-I).[36] The next step in DOE's plan for HLW management is to separate a "low-level" fraction, solidify the remainder (pri-

[35] U.S. Department of Energy National Security and Military Application of Nuclear Energy Act of 1980, Pub. L. No. 96-164, $213(a), 93 Stat.1265 (codified as amended at 42 U.S.C. §7271 (1983).

[36] At Savannah River and Hanford the liquid, acidic, high-level waste from reprocessing is neutralized (a consequence Of the decision to use carbon steel rather than stainless steel tanks for 'interim' storage), which complicates later waste treatment because sludge and salt cake are formed in the tanks.

Box 2-I—Description of High-Level Waste Tanks

Savannah River

There are 51 large concrete reinforced steel tanks located in two separate "tank farms" at the Savannah River Site. The tanks are of four different designs. Type I and II tanks are closed steel cylinders. Each tank sits inside a 5 foot-high secondary steel "pan" enclosed by a reinforced concrete support structure and topped by a thick concrete roof. There are twelve 750,000-gallon type I tanks and four 1,030,000-gallon type II tanks. Type III tanks are of similar design, with the pan forming a secondary barrier under and around the primary tank at full height. Twenty-seven type III tanks have been built to date, each with a 1.3-million-gallon capacity. Types I, II, and III tanks also have waste cooling capacity. Type IV tanks are older, uncooled, single-wall tanks used for storage of waste that does not require auxiliary cooling. There are 12 type IV tanks, each capable of holding 1.3 million gallons.

None of the type III tanks has developed any leaks; to date, five type I tanks have leaked detectable amounts of waste into the secondary steel pan; all four type II tanks have leaked significant amounts. (Waste from one tank (16H) overflowed its secondary pan on one occasion.) One type IV tank (20) developed leaks in the steel liner, and the waste has been removed from that tank.

SOURCE: U.S. Department of Energy, "Savannah River Waste Management Operations Program Plan—FY1989," DOE/SR-WM-89-1, December 1988.

Hanford

There are 177 tanks located in 18 "tank farms" at the Hanford Reservation. The Hanford tanks are of five different designs. There are 149 type I through IV tanks; each is a reinforced concrete cylinder lined with a single layer of carbon steel. The 28 newer type V tanks are built with secondary carbon steel barriers in what is known as the "tank-within-a-tank" design. The lined cylinders are then capped by concrete roofs and covered under 1.8 to 2.7 meters (5.9 to 8.8 feet) of soil and gravel.

The capacities of the tanks range from 210 to 4,300 cubic meters (55,476 to 1.137 million gallons) distributed as follows:

Type	Numbers built	Capacity in cubic meters	(gallons)
I	16	210	(55,476)
II	60	2,000	(528,344)
III	48	2,800	(739,682)
IV	25	3,800	(1.004 million)
V	4	3,800	(1.004 million)
V	24	4,300	(1.137 million)

None of the newer type V tanks has been known to leak. However, DOE officials have identified definite or possible leaks in 66 of the 149 type I through IV tanks since 1959, with the estimated leakage volume currently ranging between 670,000 and 900,000 gallons. Unlike Savannah River, where tank leakage can be determined by the presence of liquid in the secondary pans, leaks in the single-shell tanks at Hanford are detected by monitoring liquid levels in the tanks and levels of radiation in the dry wells near the tanks. Because DOE cannot measure liquid levels in many of the older tanks, detection and estimation of the amount of leakage depend mostly on dry well monitoring.

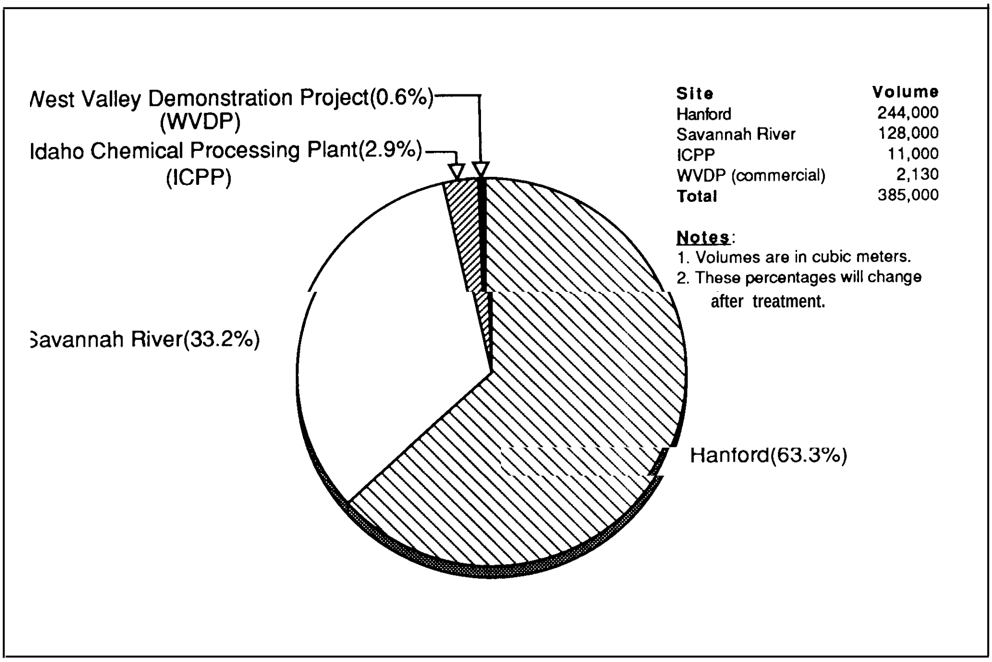
SOURCES: U.S. Department of Energy, "Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes," DOE/EIS -0113, vol. 2, December 1987; U.S. General Accounting Office, "DOE's Management of Single-Shell Tanks at Hanford, Washington," GAO/RECD-89-157, July 1989.

marily by turning it into a glasslike form through vitrification),[37] and then dispose of the vitrified waste in the Federal geologic repository at Yucca Mountain. This plan applies directly to the sites at Savannah River and Hanford where most of the high-level waste is now stored as liquid, sludge, or slurry in underground tanks.[38] After separation, the low-level fraction of this waste will be mixed with

[37] Vitrification at Savannah River and Hanford involves mixing the waste with borosilicate glass material and melting the mixture at high temperature so that it solidifies into a glasslike solid.

[38] At INEL, high-level waste is now stored in dry, granular form ("calcine"), and treatment options to prepare this form for repository disposal are being studied.

Figure 2-4-Total Volume of High-Level Waste Through 1988



SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOE/RW-0006, November 1989.

volume than the sludge) would be processed for disposal as low-level waste.[44] Over the past several years, many concerns have been raised about the leakage of high-level tank waste and possible explosions within tanks. DOE and its contractors have recently been evaluating hydrogen gas generation in both the older single-shell tanks and the newer double-shell tanks at Hanford, which could conceivably reach ignitable or even explosive concentrations. DOE is also studying methods to reduce the likelihood of such occurrences (16).

At Idaho, the high-level waste (about 3 percent of the total volume and 6 percent of the radioactivity within the Weapons Complex) has been handled differently from the other two sites. For the last 25 years, instead of neutralizing the waste so that carbon steel storage tanks could be used as at Hanford and Savannah River, INEL has been converting liquid high-level waste into a white powdery solid material known as "calcine" and storing it in underground stainless steel bins inside concrete vaults. At some future date the calcine will be immobilized (by a method as yet undetermined) and eventually placed in a repository. Prior to calcining, the acidic liquid waste is stored in stainless steel underground tanks at the Idaho Chemical Processing Plant (ICPP). These tanks, however, have been judged incapable of meeting all environmental regulations and DOE orders. Thus, five of the eleven 300,000-gallon-capacity (underground) storage tanks are expected to be replaced by four new stainless steel tanks by 1997. Figure 2-6 shows existing and planned HLW management facilities at each of the DOE sites.

DOE plans to dispose of high-level waste within the Weapons Complex in a deep geologic repository. Because of Congressional action, the only site being examined at present for an HLW repository is at Yucca Mountain in Nevada. If a repository is built there, it will not be able to accept waste until the second decade of the 21st century, at the earliest (16). The repository, which would accept commercial spent fuel as well as high-level weapons waste, would have to be licensed by the NRC. The facility would also have to comply with applicable EPA environmental standards for disposal of spent fuel

[44] The 149 single-shell buried tanks containing high-level waste are not included in this plan, and no final plan has been adopted for these tanks. For additional information, see reference 16.

cement, solidified, and disposed of in large concrete vaults at Hanford and Savannah River. These near-surface or above-surface vaults at each site will contain the waste in a form believed by DOE to be sufficiently immobile to meet requirements for safe disposal. The vaults will cover large areas and require long-term monitoring. DOE's plan for transuranic waste is to transport it by truck to WIPP from the various sites at which it is stored in 55-gallon drums.

In addition to the above, much low-level radioactive waste and hazardous waste is generated at every DOE facility as a result of daily operations. In general, low-level radioactive waste is disposed of in shallow trenches at each site (Savannah River, INEL, Oak Ridge, Hanford, Los Alamos, Nevada Test Site) or shipped off-site (from Pinellas Plant, Mound Plant, Fernald) for burial. At some sites, improved disposal practices for low-level waste are in use with controlled drainage and monitoring. At most sites, nonradioactive hazardous waste is shipped to a commercial treatment and disposal facility.

Regulatory Context of Waste Management

DOE's waste management programs at the Weapons Complex are subject to several Federal laws, including the Atomic Energy Act, as amended (AEA),[39] and RCRA. These laws, as well as regulations and DOE orders, define categories of waste (e.g., HLW and hazardous waste). The laws also assign responsibility over these wastes to various Federal agencies. DOE has authority over the storage and treatment of HLW on site (including the proposed vitrification of HLW and interim storage of the resulting glass logs), and the management of TRU waste at weapons sites.

Much of the radioactive waste on DOE sites is mixed with waste defined by RCRA as hazardous waste, and thus is subject to regulation by EPA or the States under RCRA. Historically, DOE did not have a separate program for mixed waste because it managed this waste under AEA authority only with regard to its radioactive constituents. Until the mid-1980's, DOE maintained that the AEA exempted this waste from regulation under RCRA. Following a Federal court decision rejecting DOE's position regarding RCRA hazardous waste at the Y-12 Plant,[40] DOE eventually issued an interpretative ruling confinning and clarifying that RCRA applies to the hazardous component of mixed Waste.[41] DOE has issued several internal orders governing the management of radioactive and mixed waste at the weapons sites.[42]

Storage, Treatment, and Disposal of High-Level Waste

High-level waste is stored at three weapons sites: Savannah River and Hanford (which together have more than 96 percent by volume of the HLW in the Weapons Complex and 92 percent of the radioactivity (17)) and Idaho.[43] Figures 2-4 and 2-5 illustrate the amounts of high-level waste at each site.

High-level waste stored in underground tanks (see box 2-I) at Savannah River (about 34 million gallons of waste) is awaiting vitrification at the newly constructed Defense Waste Processing Facility (DWPF), which is planned to begin operating with radioactive materials in 1992 or 1993. A waste storage building has been constructed on-site to store 2,300 canisters of the vitrified HLW "glass logs" (approximately 5 years of DWPF production). DOE hopes eventually to ship these to the Yucca Mountain repository. DOE intends to manage the radioactive salt solution fraction from the HLW vitrification process as low-level waste, and to treat and process it in the newly constructed Saltstone Manufacturing and Waste Facility. That facility began treating some low-level waste in 1990. The waste will be disposed of on-site in above-ground concrete vaults (16).

At Hanford, DOE intends to vitrify the "high-activity fraction" (mostly in the form of sludge) of the 20 million gallons of high-level radioactive waste now stored on-site in double-shell tanks, in a facility whose construction has not yet begun but that is planned to be operational in 1999 (the Hanford Waste Vitrification Project). Liquid from the pretreatment process (which has a much larger

39Atomic Energy Act, 42 U.S.C. §§201 1-2296 (1982 and Supp. IV 1986).

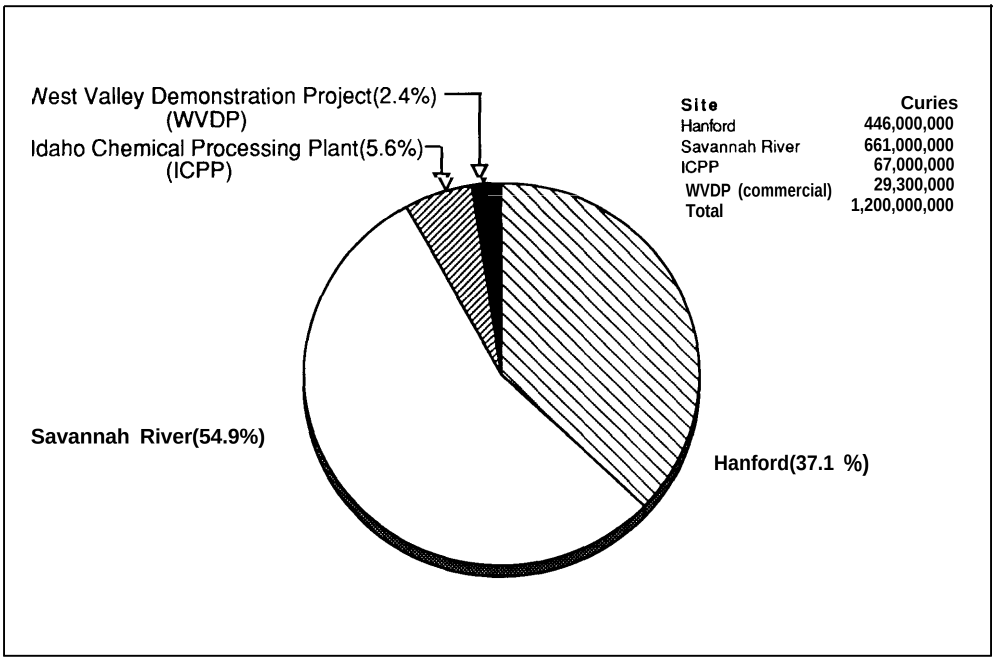
40*Legal* Environmental Assistance *Foundation* v. *Hodel*, 586 F.Supp. 1163 (E.D. Tenn. 1984).

41Radioactive Wrote; Byproduct Material, 52 Fed. Reg. 15937 (1987).

42E.g., DOE Orders 5820.2A (Radioactive Waste Management) and 5400.3 (Hazardous and Radioactive Mixed Waste Program).

43A fourth location at West Valley, NY, although not a weapons site, also has high-level waste that falls within the purview of DOE and is being treated in a fashion similar to Savannah River and Hanford.

Figure 2-5-Total Radioactivity of High-Level Waste Through 1988



SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOHRW-0006, November 1989.

and defense high-level waste.[45] The standards are not expected to be reissued until late 1990 and may not be adopted until 1992. Because essentially all high-level waste is mixed waste, RCRA regulations would also apply.

Storage, Treatment, and Disposal of Transuranic Waste

Prior to 1970, tmnsumnic waste was disposed of in the same manner as low-level waste---by shallow land burial; since 1970, however, it has been retrievable stored (mostly in 55-gallon metal drums placed on concrete or asphalt pads) at several sites including Idaho (61 percent, the largest volume), Oak Ridge (which has most of the TRU waste that must be remotely handled because of its high radioactivity), Hanford, Rocky Flats, Los Alamos, and Savannah River. A portion of the stored TRU mixed waste is in containers that are reaching their design lifetime of 20 years (16). Table 2-5 shows the estimated dates when the storage capacity for TRU mixed waste will be exceeded at individual weapons sites.

Mixed transuranic waste constitutes a large portion of retrievable stored TRU waste at the Weapons Complex sites. Mixed waste contains both a hazardous waste component subject to RCRA and a radioactive waste component regulated under AEA. Mixed transuranic waste is thus subject to the 1984 amendments to RCRA-the Hazardous and Solid Waste Amendments (HSWA)-which prohibit land disposal of hazardous waste that does not meet treatment standards established by EPA,[46] unless EPA grants a "no-migration" variance to a waste, a national capacity variance for 2 years beyond the statutory deadline, or a case-by-case extension.[47]

In January 1990, DOE provided EPA with its "National Report on Prohibited Waste and Treatment Options" (18); this included data showing that DOE lacks treatment capacity for mixed waste. After reviewing this and other data sources, EPA found that a capacity shortfall of treatment technologies for "Mixed RCRA/Radioactive Wastes" exists on the national level.[48] In recognition of this lack of treatment capacity, EPA granted a 2-year national

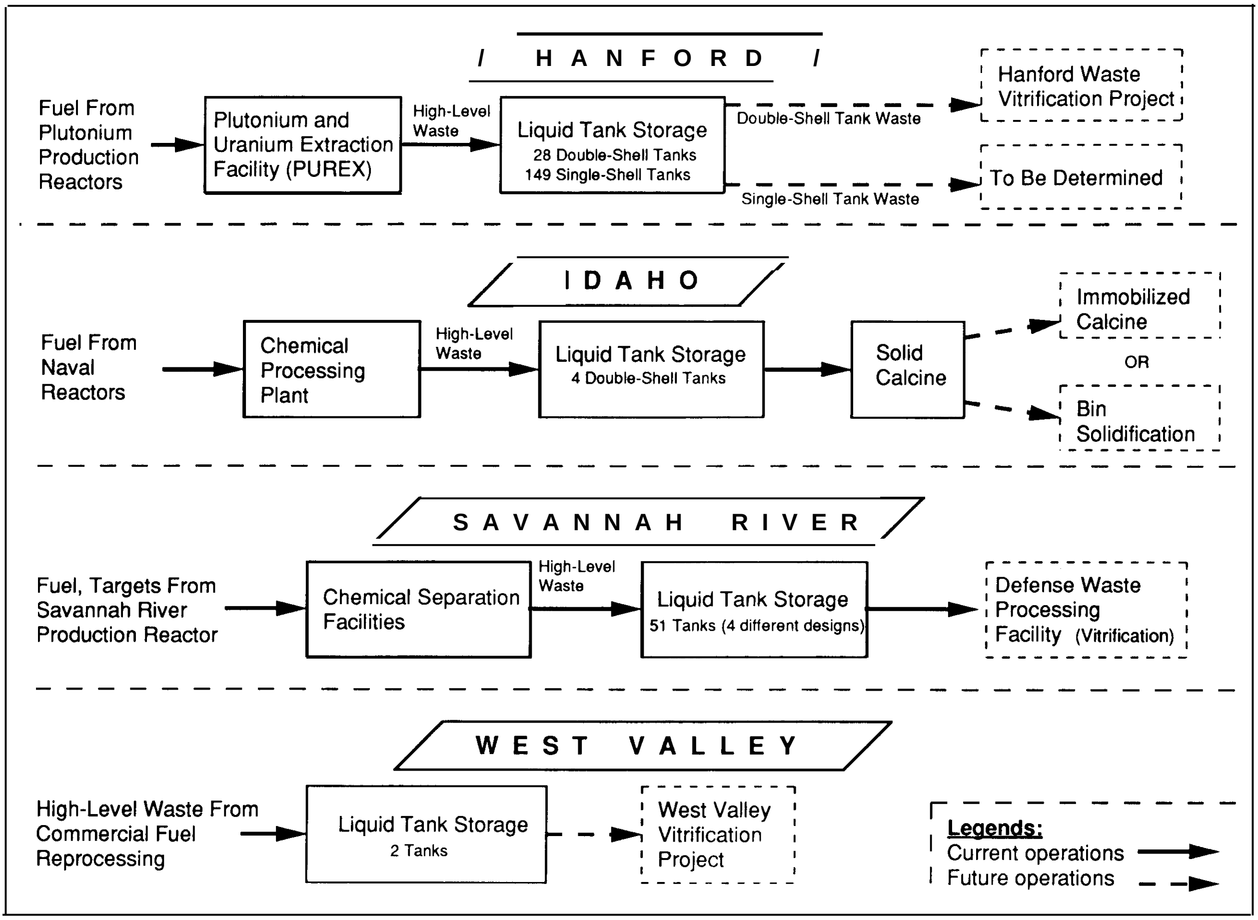
[45] EPA standards for future disposal of HLW and TRU waste, which were promulgated in 1985 (40 CFR 191, Subpart B), were vacated and remanded to EPA for further proceedings by the U.S. Court of Appeals for the First District (*NRDC* v. *USEPA, No. 85-1915 [26* ERC 1233] (lst Cir. 1987)).

[46] 42 U.S.C.A. $6924(m)(l) (West Supp. 1990).

[47] 42 U. S.C.A. §§6924(d)(1), (e)(l), (g)(5), (h)(2), and (@(3) (West Supp. 1990).

[48] Land Disposal Restrictions for Third Third Scheduled Wastes, 55 Fed. Reg. 22520, 22645(1990).

Figure 2-6-High-Level Waste at DOE Facilities



SOURCE: Office of Technology Assessment, 1991; based on DOE data, 1990.

capacity variance from the May 8, 1990 effective date of the Land Disposal Restrictions.

In addition to prohibiting land disposal of hazardous waste, HSWA prohibits storage of land-disposal-restricted waste unless "such storage is solely. . .to facilitate proper recovery, treatment, and disposal.'[49] Thus, mixed transuranic waste is subject to the land-disposal-restricted waste storage prohibitions promulgated by EPA.[50] Acknowledging the current shortage of treatment or disposal capacity (and citing an OTA report (15)), EPA announced on June 1, 1990, its intent to issue a policy on the mixed waste storage issue.[51]

Most transuranic waste (including mixed TRU waste now stored at weapons sites) is to be assayed and certified[52] for what DOE hopes will be eventual shipment to WIPP. Between 1992 and 1999, DOE plans to begin operating six new facilities to process, treat, and certify certain transuranic waste prior to shipment to WIPP. The technologies to be used will

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@42 u. S.C.A. $6924(j) (West Supp. 1990).

[50]Prohibitions on Storage of Restricted Waste, 40 CFR $268.50 (1989).

[51]Land Disposal Restrictions for Third Third Scheduled Wastes, 55 Fed. Reg. 22520,22673 (1990).

[52]Prior t. disposal at WIPP, TRU waste packages must meet waste acceptance criteria. A Waste Acceptance Criteria Certification Committee, with representatives from EPA, the State of New Mexico, and DOE established criteria to be used to certify that TRU waste is in an acceptable form for placement at WIPP. Criteria for contact-handled TRU waste and remote-handled TRU waste were established in 1980. The waste must also correspond to the definition of TRU waste, which currently excludes TRU-contaminated materials with alpha radioactivity lower than 100 nanocuries per gram.

Table 2-&Waste Groups, Applicable RCRA Program Authority, and Storage Availability for Radioactive Mixed Waste (RMW) Regulated Under the Land Disposal Restrictions, by DOE Nuclear Weapons Complex Facility

Nuclear Weapons Complex site	Class of radioactive waste mixed with the hazardous waste stream	RCRA RMW program authority: Responsible agency	RCRA RMW program authority: Facility's RCRA permit status	Type of storage and availability: Primary form of storage	Type of storage and availability: Date capacity will be reached
Fernald	LLW	EPA	Interim status	Drums	October 1990
Hanford	LLW, HLW, TRU[a]	State (since Nov. 23, 1987)	Interim status	Containers; single- and double-shell tanks	Indefinitely?
INEL	LLW, HLW, TRU[a]	EPA	Interim status	Underground tanks and steel bins; concrete vaults	1993 (if additional construction is approved)
Kansas City	LLW	EPA	Interim status	Containers	Adequate fortheforeseeable future
LLNL	LLW	EPA	Interim status	Containers; portable tanks	Adequate fortheforeseeable future
Mound Plant	LLW	EPA	Interim status	Containers	Mid-1990
Nevada Test Site	TRU[a]	EPA	Interim status	Drums; containers	
Oak Ridge	LLW	State (since Aug. 11, 1987)	Interim status	Containers	Mid-1990
Oak Ridge Y-1 2 Plant	LLW	State (since Aug. 11, 1987)	Interim status for some units, final permit for others	Tanks; waste piles; drums	1998 for some waste
Pantex Plant	LLW	EPA	Interim status	Drums	Adequate fortheforeseeable future
Rocky Flats	TRU, LLW	State/EPA[b]	Interim status	Drums; tanks; containers	Mid-1990 for TRU waste and late-1990 for solvents
Sandia laboratory	TRU, LLW[a]	EPA	Interim status	Containers	?
Savannah River Site	HLW, TRU, LLW	State (since Sept. 13, 1987)	Interim status	Underground tanks and containers	Adequatefortheforeseeable future

[a]Additional waste characterization is necessary not only to confirm the presence of these radioactive waste streams but also to eliminate any uncertainty that this waste is to be regulated under Land Disposal Restrictions.

[b]Although the State of Colorado has the authority to regulate mixed radioactive waste, authority to enforce the Land Disposal Restrictions of RCRA still remains with EPA.

SOURCE: U.S. Department of Energy, "National Report on Prohibited Wastes and Treatment Options—As Required by Rocky Flats Plant Federal Facilities Compliance Agreement Dated September 19, 1989," Jan. 16, 1990.

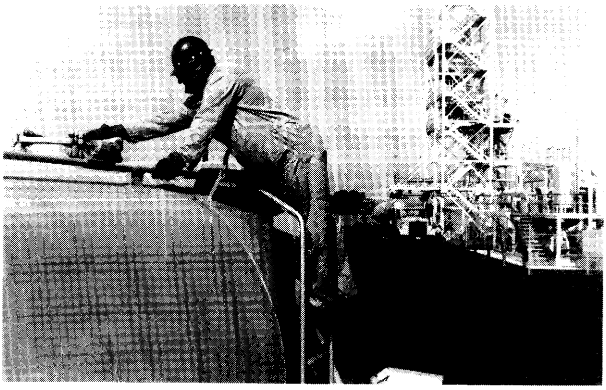


Photo credit: U.S. Department of Energy

Checking seal on tank truck after unloading at the grout facility at Hanford.

include shredding, incineration, compaction, and immobilization in grout. The only newly constructed TRU mixed waste incineration facility (at INEL) has encountered technical problems and may not begin operating for some time. DOE has not decided how to deal with the portion of transuranic waste that is not certifiable (16).

Transuranic waste (including mixed TRU waste) from Rocky Flats, Mound Plant, and other weapons sites was shipped to Idaho until September 1989, when the Governor closed State borders to additional TRU waste. DOE's plans call for transportation of transuranic waste to WIPP when it opens, with waste from Rocky Flats and INEL among the earliest shipments. The waste will have to be transported over long distances in a fleet of trucks, each carrying three shipping containers (which were granted a Certificate of Compliance by the NRC in August 1989); each container would, in turn, hold 14 waste drums (see figure 2-7). It will take 20 to 30 years for weapons site or yet-to-be-generated waste to be disposed of at WIPP. Waste would remain on-site until its turn to be sent to WIPP.

DOE plans to dispose of all transuranic waste (including TRU mixed waste) now retievably stored in the Weapons Complex at WIPP, a geologic repository excavated from salt formations 2,150 feet underground near Carlsbad, NM. Construction of a substantial portion of WIPP was completed in 1989. According to DOE, WIPP has the capacity to handle newly generated as well as presently stored transuranic waste. DOE's current program for managing stored transuranic waste contemplates the construction of six new facilities at various sites (19) during 1992-1999 for processing, treating, and certifying transuranic waste prior to shipment to WIPP.[53] The full extent and nature of treatment, however, have not been specified.

DOE's plan for disposing of retrievable stored transuranic waste depends on the availability of WIPP as the disposal facility. However, the opening of WIPP for preliminary tests was delayed from the initially projected date of October 19, 1988, and more recently projected opening dates have also not been met. Before making a decision to store transuranic waste at WIPP on a permanent basis, DOE plans to conduct tests for about 5 years, in accordance with its plan for the WIPP Test Phase (20). After experimental emplacement in WIPP of a limited number of TRU-filled bins, tests would be conducted to evaluate the potent@ problem of gas generation in the waste package (26). Alcove tests would also be performed to examine the interaction between waste and the surrounding salt medium.

Secretary of Energy James D. Watkins announced his decision in June 1990 that WIPP was ready to proceed with the test phase.[54] In addition, DOE's No-Migration Variance Petition under RCRA was approved by EPA in November 1990.[55] Before WIPP can be actuated, however, the land on which WIPP is located must be withdrawn from the jurisdiction of the Department of the Interior. Legislation to accomplish this was proposed by the Administration in 1990 but was not passed.

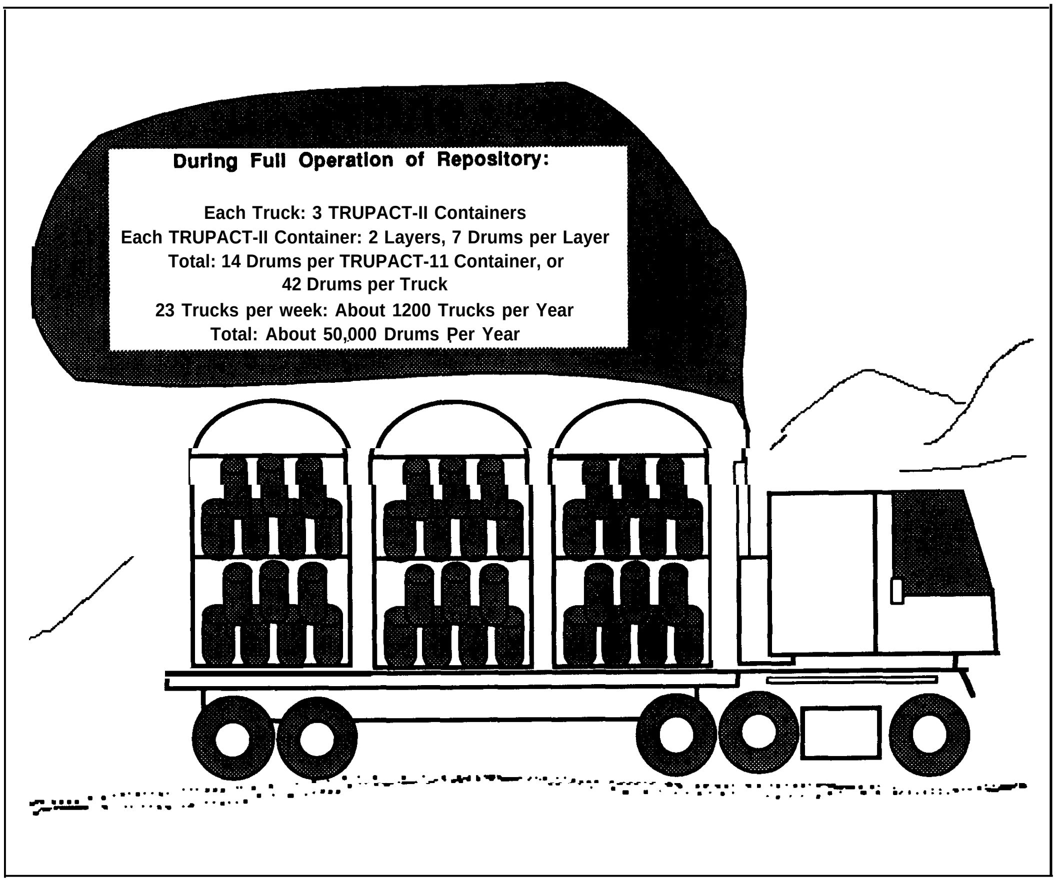
The proposed legislation also called for DOE to comply with EPA standards for disposal of transuranic waste and for EPA to establish such standards within specified time frames. Only after completing the test phase would DOE be able to declare whether the facility is suitable for the disposal of transuranic waste. If suitable, DOE would then have to operate WIPP in accordance with new environmental standards for the disposal of transuranic waste to be promulgated by EPA.

[53]Sites are INEL, Savannah River, Hanford, and Oak Ridge.

[54]Record of Decision, Waste Isolation Pilot Plant(WIPP), 55 Fed. Reg. 25689 (1990).

[55]Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant (WIPP), 55 Fed. Reg. 47700 (1990).

Figure 2-7—Bringing Trucks of TRU Waste Drums to WIPP



SOURCE: Office of Technology Assessment, 1991.

Storage, Treatment, and Disposal of Mixed Waste

Most of the radioactively contaminated hazardous waste, also known as "mixed waste,' at DOE weapons facilities results from the production of defense and research materials and from recycling or reprocessing spent fuels and obsolete weapons. DOE facilities were generally not designed for on-site treatment and disposal of mixed waste. The management of mixed waste has traditionally been based on storing it at the generating facility until long-term radioactive waste disposal facilities become available. Waste stored at the Weapons Complex has increased substantially in recent years. In 1988 DOE reported a projected increase of more than 11 percent in on-site storage of transuranic waste compared with the 1986 total (21).

At the same time, DOE's available on-site waste storage capacity has diminished rapidly, and some of the capacity needed for mixed waste is currently being utilized to manage radioactive waste as well as RCRA-restricted hazardous waste (22).[56] Fernald, Mound Plant, Oak Ridge National Laboratory, and Rocky Flats (for certain waste) are on the verge of running out of capacity for storing mixed waste. Storage capacity at eight other Nuclear Weapons Complex facilities is expected to be reached by the mid-1990's.

Several regulatory and technical issues are associated with present and future mixed waste management at the complex. Mixed waste must be managed in compliance with specific treatment and disposal requirements established under RCRA's Land Dis-

[56] Leo P. Duffy, Director, DOE's office of Environmental Restoration and Waste Management, testimony before the House Armed Services committee, Mar. 15, 1990, p. 12.

posal Restrictions (LDRs). (Mixed waste placed in storage before the LDR effective dates, however, is not subject to RCRA, unless it is moved from its current place of storage (23).) Interagency agreements among DOE, EPA, and the States are being used to address the mixed waste issue at some sites. For example, because storage of radioactive materials contaminated with LDR waste "may be construed to violate RCRA regulations, in particular the Land Disposal Restricted Waste storage prohibitions. . ." (24), the State of Colorado and EPA signed a Federal Facility Agreement and Consent Order with DOE on September 19, 1989, in which DOE committed itself to comply with RCRA and State regulations. The agreement has also led to assessment of storage problems at other weapons facilities.

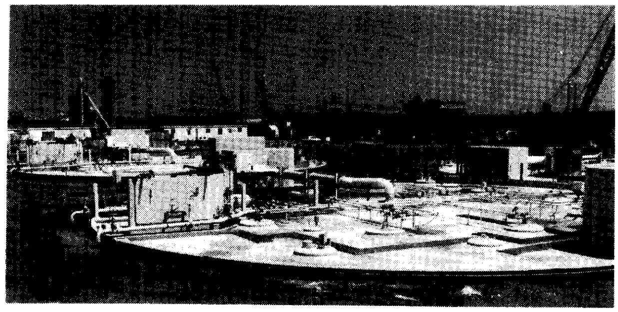


Photo credit: U.S. Department of Energy

Completed underground storage tanks for high-level waste at Savannah River. Design provides for stress relief and access to tank and annulus to measure tank liquid levels, temperature and pressure, allow inspection of tank walls, and collect samples.

Evaluation

High-Level and Transuranic Waste

DOE's strategy for ultimate disposal of high-level and transuranic waste is predicated on placement of the waste, after treatment, in deep geologic repositories. OTA finds that, in some instances, DOE has not paid sufficient attention to options that could be exercised if delays in repository openings persist. For high-level waste, if vitrification works the way its developers anticipate, treatment should create a more stable, secure waste form than exists with liquid tank storage--one that can be safely stored on-site or in a monitored retrievable storage facility for hundreds of years, given adequate institutional controls, independent oversight, and public support. However, current plans for transuranic waste treatment and storage are not adequate in the face of repository delays.

Most DOE plans for dealing with high-level and transuranic waste at the weapons facilities assume that a deep geologic repository will be available for disposal of each type of waste at some specified time in the future. Until very recently—in fact, just prior to preparation of the 1989 Five-Year Plan-DOE's disposal strategy for HLW and TRU waste was based on the assumption that a repository for high-level waste would be available by the year 2003, and a research and development facility for disposal of transuranic waste by 1988, followed soon after by an operational repository. DOE's projections have changed significantly, but its planning with regard to interim storage has not kept pace with the changing scenarios of geologic repository availability. DOE has recently focused more attention on the interim storage that will be required until the high-level waste and spent fuel repository is opened, which has now been delayed at least 7 years until 2010 (5). The interim storage period continues to grow as both repositories continue to be delayed.

For example, DOE currently assumes that the earliest possible time at which an HLW repository at Yucca Mountain could be available for shipment of defense high-level waste is the year 2015. Given that situation, any vitrified high-level waste must remain on-site longer than originally anticipated. The public has not been explicitly notified of the possible on-site storage of vitrified high-level waste for the next two to five decades, and DOE has not focused adequate attention on the waste testing and monitoring that may be required. DOE has, however, noted that "interim storage after conversion will be required until the repository is opened" (25). Yet it has not analyzed all the impacts of longer storage or detailed plans for possibly further delays in the availability of a high-level waste repository. Additional delays of more than 5 years could mean that Savannah River and Hanford (and perhaps even INEL) would have to provide longer and more extensive interim storage than originally planned.

DOE's strategy for vitrifying high-level waste, although costly, appears to be an important step in the right direction. It is not clear, however, whether the time frame for vitrification is such that liquid high-level waste will be immobilized soon enough to avoid potential problems with waste tanks. Because of the importance of vitrification, independent technical oversight of its development and greater regulatory oversight of the waste form may be required.

Delays in opening WFP have already necessitated some longer interim storage of transuranic waste than initially planned. WIPP maybe available for testing stored transuranic waste disposal in 1991. If the test phase is followed by a prompt positive decision to open WIPP and no further delays occur, the earliest date for disposal of waste at WIPP on an operational basis is 1995. In the meantime, stored transuranic waste intended for WIPP must remain where it is or be transferred to some other site for storage until WIPP opens. DOE has recognized this problem and suggested a number of alternatives, including transferring some of the waste to privately operated storage facilities.

Under current DOE plans, transuranic waste destined for WIPP will be given minimal treatment. Fifty-five-gallon drums are loosely packed with contaminated clothing, paper, metal scraps, and other items. The drums were designed to last for 20 years, and some are already this old. The transuranic waste is generally not immobilized within the drums. Additional treatment and storage options must be considered now if this tmnsuranic waste is to be managed safely. Furthermore, much of the transuranic waste is mixed waste whose treatment requires complex facilities yet to be built. Treatment standards for this waste have been developed by EPA, but DOE does not have to demonstrate compliance immediately because of EPA's 2-year capacity variance.

DOE's strategy of minimal treatment of the transuranic waste form prior to disposal at WIPP, although less costly than other options, is problematic for two reasons. First, there is the question of whether the waste form will be able to meet EPA disposal standards fortransuranic waste under human intrusion scenarios. Second, interim storage of TRU waste would appear to be precluded for more than the short-term (i.e., 20 years), given the current storage of loose waste in drums.

There appears to be only one site-Rocky Flats—for which DOE has begun to plan alternative storage approaches for transuranic waste. However, at least one of those approaches—storing Rocky Flats waste at other DOE sites—has been opposed by the Governors of affected States. The other two approaches---commercialization of disposal and use of Defense Department sites—will raise regulatory, political, and other questions. Furthermore, there is little in the 1990 Five-Year Plan to indicate how DOE will deal with the implications of this longer interim storage at the six principal sites other than Rocky Flats, where transuranic waste is now stored (26).

Photo credit: U.S. Department of Energy

Low-level waste in compacted drums being packed into steel boxes for off-site shipping from Fernald.

In addition, considerable confusion surrounds the applicable standards for DOE's radioactive waste management program. Box 2-J illustrates the slow pace and complexity of radiation standard development. Attention to adequate standards and competent oversight are necessary to assure the public that it is being protected while waste is managed at DOE sites.

Mixed Waste

DOE's problems are also complicated by the regulatory implications of its actions or lack of action regarding mixed waste. Mixed waste (particularly mixed transuranic waste) is difficult for the weapons sites to manage because regulatory limits on storage capacity do not exist. The time for which mixed waste can be stored on-site is generally limited by law, or regulations. In early 1990, DOE published a report on prohibited wastes and treat-

Box 2-J—Radiation Protection Standards in Limbo

EPA can promulgate generally applicable environmental radiation protection standards for low-level and high-level waste management facilities but has no enforcement authority.

As a result of Reorganization Plan No. 3 of 1970,[1] the Atomic Energy Act of 1954,[2] the Low-Level Radioactive Waste Policy Act of 1980,[3] and the Nuclear Waste Policy Act of 1982,[4] EPA was given the authority to promulgate generally applicable environmental standards for the management, storage, and disposal of low-level and high-level radioactive waste. The goal of these standards is to establish exposure radiation limits to ensure the protection of individuals and the general public. Compliance by DOE with EPA standards, however, need only be demonstrated at the facility boundary because the authority to implement and enforce these standards at sites themselves resides in DOE. According to some EPA officials, this anomaly must be corrected so that public health and environmental safety are ensured.

EPA standards to protect the public and the environment against radiation from DOE's low-level radioactive waste management and disposal activities are still being developed.

Under the authority of the Atomic Energy Act, EPA proposed a radiation protection limit to any member of the public from all pathways of 25 millirem per year, from low-level waste disposal sites and a limit of 4 millirem per year for the protection of groundwater sources. The latter requirement has drawn considerable criticism, especially from the Nuclear Regulatory Commission, which considers it too stringent in comparison with its own limit of 10 millirem per year from groundwater.

EPA sent the proposed standards to the Office of Management and Budget (OMB) for approval. OMB has returned the proposed standards to EPA for further modification, particularly of the groundwater portion of the regulations. Approval of final regulations is not expected before 1991. In the interim, no specific Federal regulatory standards exist to protect the public from DOE's low-level radioactive waste. Commercial low-level waste management facilities, however, continue to be regulated by NRC.

EPA radiation protection standards for high-level radioactive and transuranic waste disposal are still being developed.

In September 1985, EPA proposed standards to control the management and disposal of high-level radioactive waste.[5] Immediately after their promulgation, the standards were challenged in court by several States and environmental groups. As part of the legal proceedings, in 1987 the court reinstated the section (40 CFR 191 Subpart A) that deals with the management and storage of high-level waste. Subpart B, however, was remanded back to EPA for modification and is still being changed to satisfy the court's requirements. Issuance of final Part B requirements may be further delayed if OMB does not approve them in a timely fashion.

[1]Reorganization Plan No. 3 of 1970, 35 Fed. Reg. 15623 (1972).

[2]42 U.S.C. Sections 2011-2296 (1982 and Supp. IV 1986).

[3]42 U.S.C. Sections 2021b-2021d (1982).

[4]42 U.S.C. Sections 10,101-10,226 (1982).

[5]Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Wastes, 50 Fed. Reg. 38066 (1985).

SOURCE: Office of Technology Assessment and footnotes 1, 2, 3, 4, and 5.

ment options. Table 2-5 summarizes the status of each DOE facility's permit and storage capacity.

Because of its past reluctance to acknowledge that certain laws and regulations (particularly RCRA) apply to weapons sites, DOE did not initiate programs to comply with those requirements until relatively recently. DOE is now having difficulty integrating the regulatory requirements governing mixed waste with its management of stored waste. While regulations allow for variances to be granted,[57] DOE has acted to obtain the variances and exceptions permitted under these regulations (e.g., the no-migration petition submitted in connection with WIPP and the delisting petitions filed by Oak Ridge). DOE should be considering alternatives (e.g. treating the waste or changing its form) in the

[57]For example, the 2-year national capacity variance from the Land Disposal Restrictions granted by EPA in May 1990.

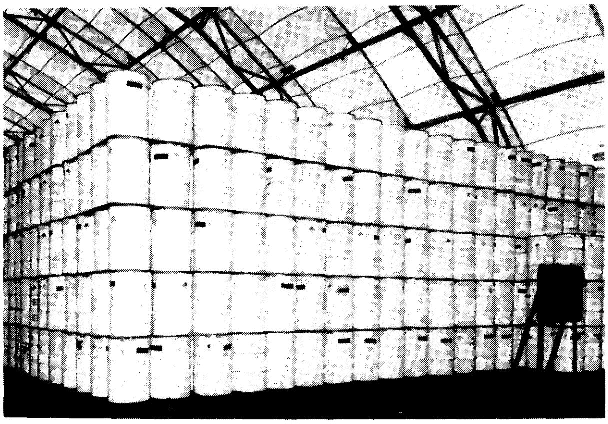


Photo credit: U.S. Department of Energy

Waste awaiting shipment to WIPP from INEL Radioactive Waste Management Complex.

event that some of its requested petitions are not granted.

In addition, in addressing the regulatory and technical issues raised by mixed waste, it may be prudent to consider regulations that more adequately address improvements in storage to reduce risks to human health and the environment-and to ensure that EPA's universal treatment technology standards do not preclude research into technological alternatives with greater potential to address the varied nature of DOE's mixed waste.

ESTIMATING COSTS

status

Over the past 2 years, DOE has provided a variety of cost estimates for waste management and environmental cleanup at the Weapons Complex (1,4,13). Other agencies and organizations have reviewed these estimates and offered their own analyses and interpretations (27,28). Only DOE has made site-specific estimates of the cost of accomplishing work under these programs, and very few of the projected cost estimates are reliable. Other analyses have used DOE estimates and applied different assumptions about what should be included, what should be given priority, or how costs should be accounted.

The most recent DOE cost estimates can be found in the 1990 Five-Year Plan in which DOE presents budget costs for FY 1990 and 1991 and planning estimates for the following 5 years (FY 1992-96). This plan covers only those activities that may be accomplished during that time. As described elsewhere in this report, work planned for the next 5 years is devoted primarily to characterizing contaminated environments, stabilizing some inactive sites at which standard techniques can be applied, and continuing to manage the large quantity of waste within each site. These latest estimates exceed the estimates contained in the 1989 Five-Year Plan by a substantial amount (see figure 2-8).[58]

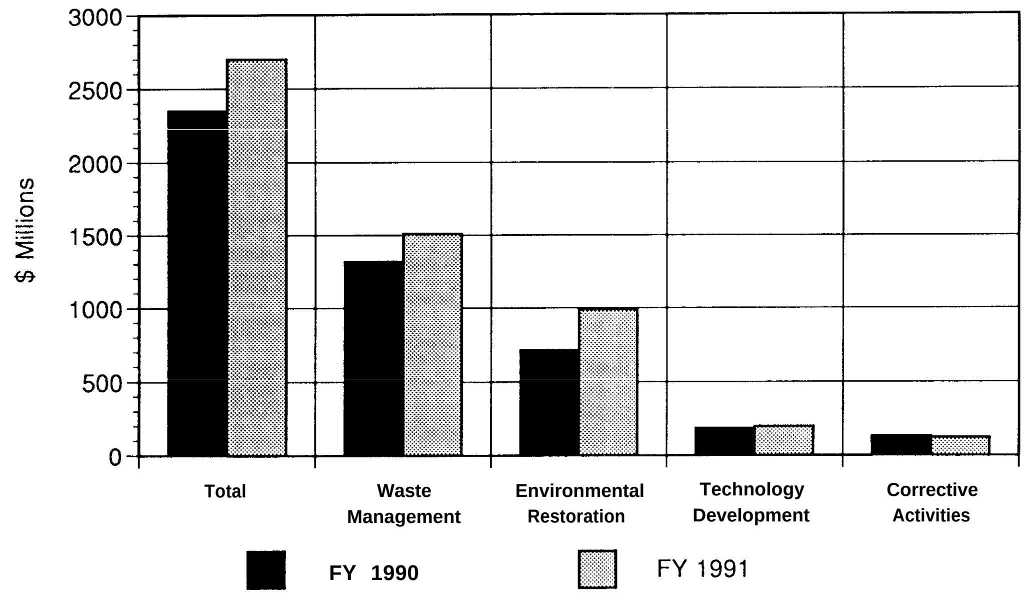
Photo credit: U.S. Department of Energy

Radiation monitoring at Hanford.

The only attempt by DOE in recent years to estimate a total cost for completion of its cleanup program was published in a 1988 report (13). That estimate, which was hastily made when data were even more unreliable than today, is the only compre-

[58]Funding requests for the President's budget are lower than the costs estimated in the 1990 Five-Year Plan. DOE has stated that the levels of funding implied by the latest cost estimates "cannot now be managed responsibly and effectively, given the inadequacy of the DOE, contractor, industry and regulatory infrastructure" (29).

Figure 2-8-DOE Budget for Environmental Restoration and Waste Management



SOURCE: U.S. Department of Energy, "Environmental Restoration and Waste Management: Five Year Plan, Fiscal Years 1992-1998," DOE/S-0078P, June 1990.

hensive baseline for understanding the magnitude (in terms of dollars) of the future DOE cleanup program at the weapons sites. That 1988 estimate put the 20-year cleanup cost at $71 billion to $111 billion. By comparison, estimates made for all environmental activities in the 1989 and 1990 Five-Year Plans for 1989 through 1996, only 8 years, amount to almost $40 billion. The uncertainties associated with even these near-term estimates cast further doubt on long-term estimates. Subsequent reviews of available cost data have not attempted to make independent detailed estimates of total cost to completion. One General Accounting Office (GAO) study in 1988 suggested that total costs could be between $115 billion and $155 billion, including modernization, but it did not substantiate this in detail (28). The 1990 Congressional Budget Office report on Federal facility environmental cleanup costs merely summarized the estimates made by DOE (30). A 1990 GAO study stated that 'according to DOE's estimates, the total cost of modernization and responding to environmental problems of the Weapons Complex could range from $125 billion to $155 billion"[59] (31).

Since 1988, DOE has not published an estimate of costs for the entire cleanup program. The reason given for its reluctance to do so is the existence of too many unknowns-especially the nature and extent of all contamin ation problems and the types of remediation that would lead to acceptable results.

Evaluation

OTA has reviewed relevant cost data prepared by DOE and analyzed by others. OTA has also investigated the quality and completeness of DOE cost estimates for some of the most recent and active cleanup projects at a number of Weapons Complex sites (see app. C). OTA's analyses have led to conclusions in three general areas: 1) the magnitude of total program costs for environmental restoration and waste management, 2) the division of costs into

[59] This estimate includes $50 billion for modernization, $35 billion to $65 billion for environmental cleanup, $15 billion for decontamination and decommissioning, and $25 billion for waste management, through 2010.

various categories, and 3) the quality of cleanup cost projections for environmental restoration.

Overall Costs

At present no data are available on which to base a reasonable estimate of cost-to-completion of the DOE weapons waste cleanup program. The only attempt at such an estimate (in 1988) was too hastily made to yield accurate results (13). Even though an overall cost estimate is difticult, a much more methodical effort to estimate the most significant costs over the next few years would be extremely beneficial to policymakers and to the Nation as a whole. Such an effort could focus on the different levels of certainty associated with various cost estimates and include explicit consideration of alternative solutions for the most difficult remediation problems. The cost estimates at different levels of certainty could then be compared with the progress made toward characterizing the sites to help determine the rate of progress toward meeting overall cleanup goals in the short term.

More data about environmental problems and solutions are available today than in 1988, and much information about contaminated sites should be coming in over the next several years. An overall cost estimate can be more realistically made when the bulk of characterization work has been completed. Even though specific approaches and their costs will have to be studied and updated continuously, a total cost accounting at that time would be more meaningful and would alert policymakers to the direction of the program as it develops toward its long-term goals.

Cost Categories

DOE's current cost estimates contained in the 1990 Five-Year Plan are generally divided into four major categories: 1) waste management, 2) environmental restoration, 3) technological development, and 4) corrective activities.[60] Figure 2-9 shows the division of the current FY 1991 budget into these four categories through 1996. DOE has allocated about 90 percent of the funds for waste management and environmental restoration, with about twice as much for the former as for the latter. Over the 7 years covered in the plan, these two categories are expected to grow from 86 to 93 percent of the budget. The remainder is allocated to corrective activities (from 6 to 2 percent) and technological development (from 8 to 5 percent).

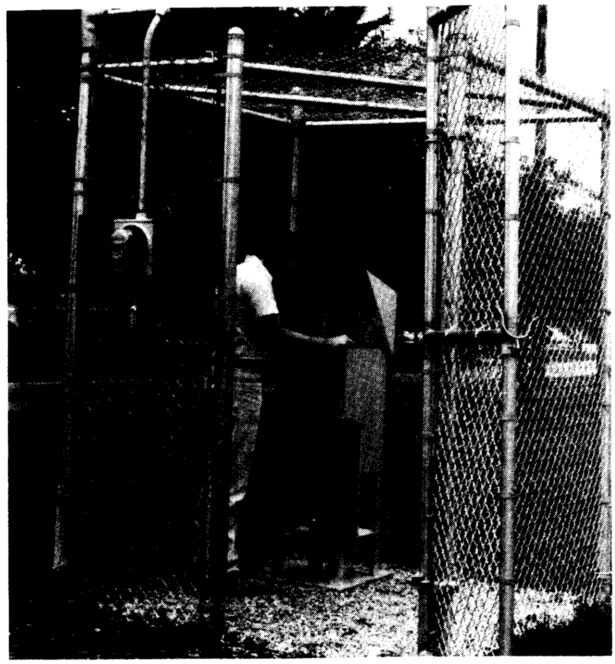


Photo credit: U.S. Department of Energy

Air monitoring station at an elementary school near Fernald collects data on airborne emissions of particulate, radionudides, and uranium.

A major factor influencing the dominant cost allocation to waste management in the Five-Year Plan is the number of large, new, and costly technologies being implemented over this time (16). In addition, serious problems with storage and treatment of certain waste must be resolved. It is therefore understandable that waste management is given high priority in the budget plan. This heavy emphasis on one category, however, will require continued scrutiny as environmental restoration decisions begin to be made a few years hence and more funds are required. If waste continues to be generated, it may be more prudent to allocate resources to solve existing contamination problems frost and then to focus on *minimizing* future waste generation.

Reliability of Environmental Restoration Costs

Although the DOE Five-Year Plan is a good approach to planning budget allocations in the near term, most of the current environmental restoration

[60] A fifth category, transportation, contains relatively small amounts of funds and is omitted from this discussion.

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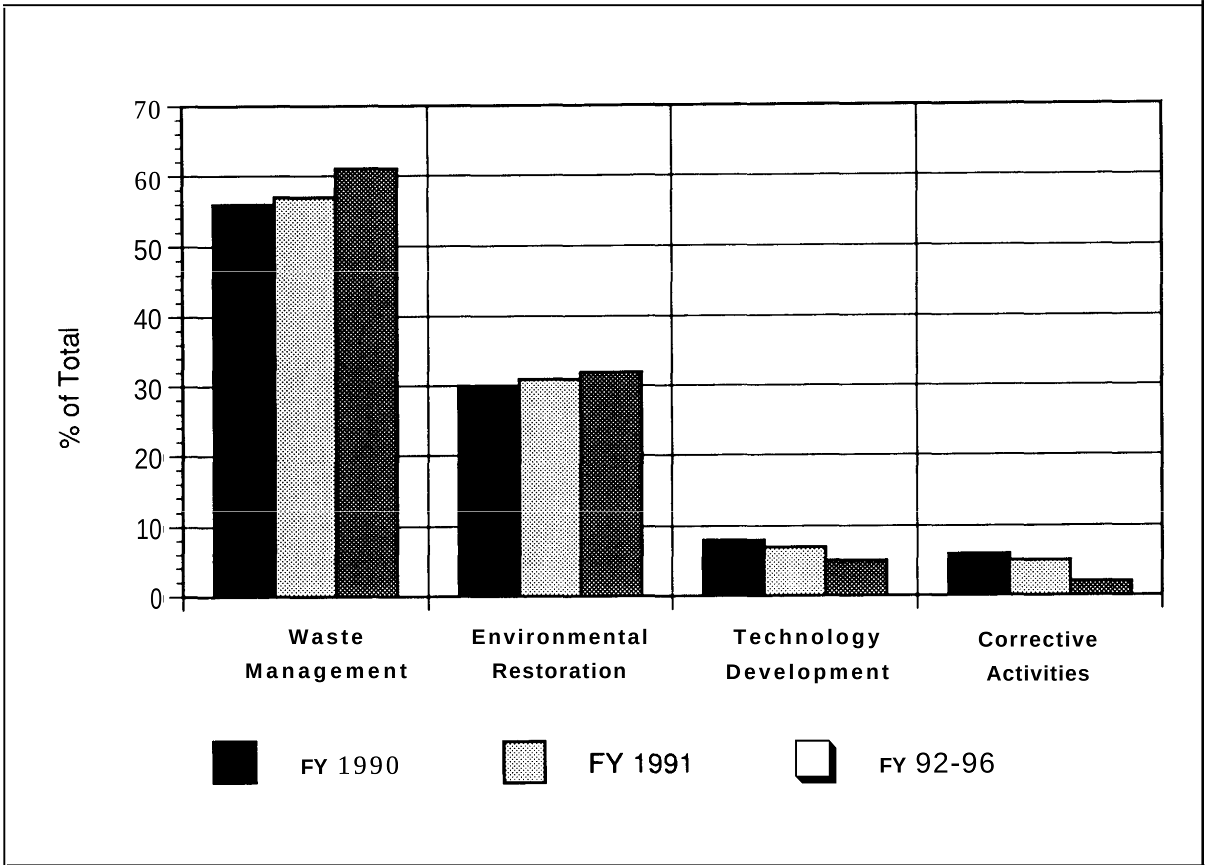
Figure 2-9-Cost Categories for Waste Management and Environmental Restoration Program



SOURCE: U.S. Department oi Energy, "Environmental Restoration and Waste Management: Five Year Plan, Fiscal Years 1992-1998," DOEK3-0078P, .June 1990.

costs are for studies and assessments to characterize the problem, not for remediation activities. OTA analysis indicates that recent estimates of the cost of cleanup projects are unreliable in many areas and are inconsistent throughout the Weapons Complex. To evaluate estimated and actual costs involved in remedial activities, OTA investigated the costs of all remediation projects that DOE was willing and able to provide (see app. C). The sample was from nine weapons facilities at which some remediation is either complete or underway. It included ground-water pumping and monitoring, pond stabilization and closure, centaminated soil removal, and a grouting demonstration project.

OTA analyses of these case studies show that the costs for similar activities, both estimated and actual, vary significantly from facility to facility and even from site to site in one facility (see table 2-6). Because data are extremely limited and so few projects have been completed, it is dificult to draw any conclusions about this variation. Variations may be due to legitimate technical differences at each facility or to accounting differences. The implications are, however, that a close accounting must be made of the costs of remedial actions to improve DOE's ability to estimate costs accurately and verify instances in which cost savings maybe attributed to better technology, improved management, or variations in cleanup standards. At present, no data are available to support the claim that technological development will reduce cleanup costs by any significant amount. Although certain technological approaches hold promise in this area, much more work must be done to evaluate where cost savings might result and where cost increase would be the outcome (both cost savings and cost increase have been documented in past studies; see app. C).

Table 2-6-Some Typical Ranges of Costs for Environmental Restoration Projects

Type of project	Cost ranges from OTA ease studies
Installation of groundwater monitoring well (per foot)	$150 (Pinellas) -$417 (Hanford)
Annual sample analysis (per well)	$1,333 (LLNL) -$20,500 (INEL)
Excavation of soil and sludge (per cubic yard)	$8 (Savannah River) -$260 (Oak Ridge)
Off-site soil disposal (per ton)	$110 (Pinellas) -$146 (Kansas City)
Installation of groundwater recovery well (per foot)	$159 (Savannah River) -$400 (LLNL)
Capinstallation (persquare foot)	$5 (Oak Ridge) -$8 (oak Ridge)

SOURCE: App. C.

It is evident from OTA's analysis that these DOE cost estimates are inconsistent and difficult to compare. In some cases, for example, costs were overestimated (for Savannah River's mixed waste facility); in others, estimated accurately (the Savannah River Groundwater Remediation Project).[61] Because data are extremely limited and so few remedial actions have been completed, it is difficult to draw any conclusions from this variability. Variation between estimated and actual cost depends heavily on the project stage in which the estimate was made, as well as on the complexity of the problem. In addition, DOE project engineers have indicated that they were given too little time to accurately estimate environmental remediation costs in the preparation of both Five-Year Plans. Steps are being taken by both DOE and its prime contractors to understand and address these inconsistencies.

DOE has begun to analyze cost uncertainties associated with environmental restoration projects, and its study shows that as a project becomes more defined, estimates become more accurate (i.e., better assessment provides better cost estimates, up to a point). According to this analysis, a cost increase of more than 25 percent is not uncommon for environmental restoration projects because of the complexity of the waste, the variability of the sites, and the level of sophistication of the technology used. This information is being used to help DOE cost estimators on environmental restoration projects, along with a cost estimating handbook developed by DOE (32). These tools were not used to estimate the costs for the 1990 Five-Year Plan, however.

Also, in the limited cost information available to OTA on environmental restoration projects, no consistent relationship is apparent between estimated and actual costs. Cost overruns appear to be due primarily to the lack of detailed characterization of the contamination, especially with respect to volume, or to unforeseen circumstances such as unusually high rainfall or new information uncovered in the characterization process. Based on EPA Superfund experience, cost overruns as high as 100 percent for remedial action are not unusual (see app. C).

Closer attention to details may help in estimating future costs, but even with the best information, the cost of environmental remediation will be subject to large uncertainties. Thus, a close **accounting of the costs** of remedial actions is necessary to assess the efficiency or effectiveness of DOE's Environmental Restoration program. Such careful accounting of costs appears to have been lacking in the early years of Superfund (and may still continue), making it extremely dificult to determine the success of that program. Careful attention to unit costs could be most valuable in helping DOE to avoid such problems, if initiated early in the program.

Better estimates can be expected as more information becomes available. The use of estimating tools being developed by DOE, along with more information, could help improve cost estimates (see app. C). However, the process of estimation should be consistent throughout the Weapons Complex, and engineers should be given adequate time and resources to make such estimates.

[61]It should be noted that although cost estimates for the groundwater project at Savannah River accurately reflect actual expenditures for the plant equipment installed, the design was insufficient, additional equipment was required, and much less than the planned quantity of contaminants was removed (see app. B).

SETTING PRIORITIES

Status

As with most federally funded programs, priorities for funding environmental restoration and waste management activities at the Weapons Complex are set through the annual budget process. Apart from that process, DOE has attempted to establish a more rigorous system to guide its own decisions regarding environmental restoration and waste management activities, both to support its budget request and to allocate appropriated funds. Thus far, these attempts have been directed primarily at DOE's relatively new internal 5-year plarming process, rather than the annual budget cycle.

In the 1990 Five-Year Plan (33), a DOE-wide, four-level priority system is set forth for allocating funds to environmental restoration and waste management activities. The categories encompass the following types of activities:

1. those necessary to prevent near-term adverse impacts on workers, the public, or the environment, including containment to prevent the spread of contamination and waste management activities to maintain safe conditions (also included in this category is the continuation of ongoing activities that, if terminated, could have significant negative effects);
2. those necessary to meet the terms of agreements between DOE and local, State, or Federal agencies;
3. all other activities required to reduce risks, promote compliance, reduce public concern, and maintain DOE missions; and
4. activities with no pressing time constraints, such as decontamination or decommissioning.

In practice, most activities fall into priority 1 or 2. Because priority 2 includes milestone; set by all the interagency agreements that have been signed, it would be difficult for DOE not to assign these activities top priority.

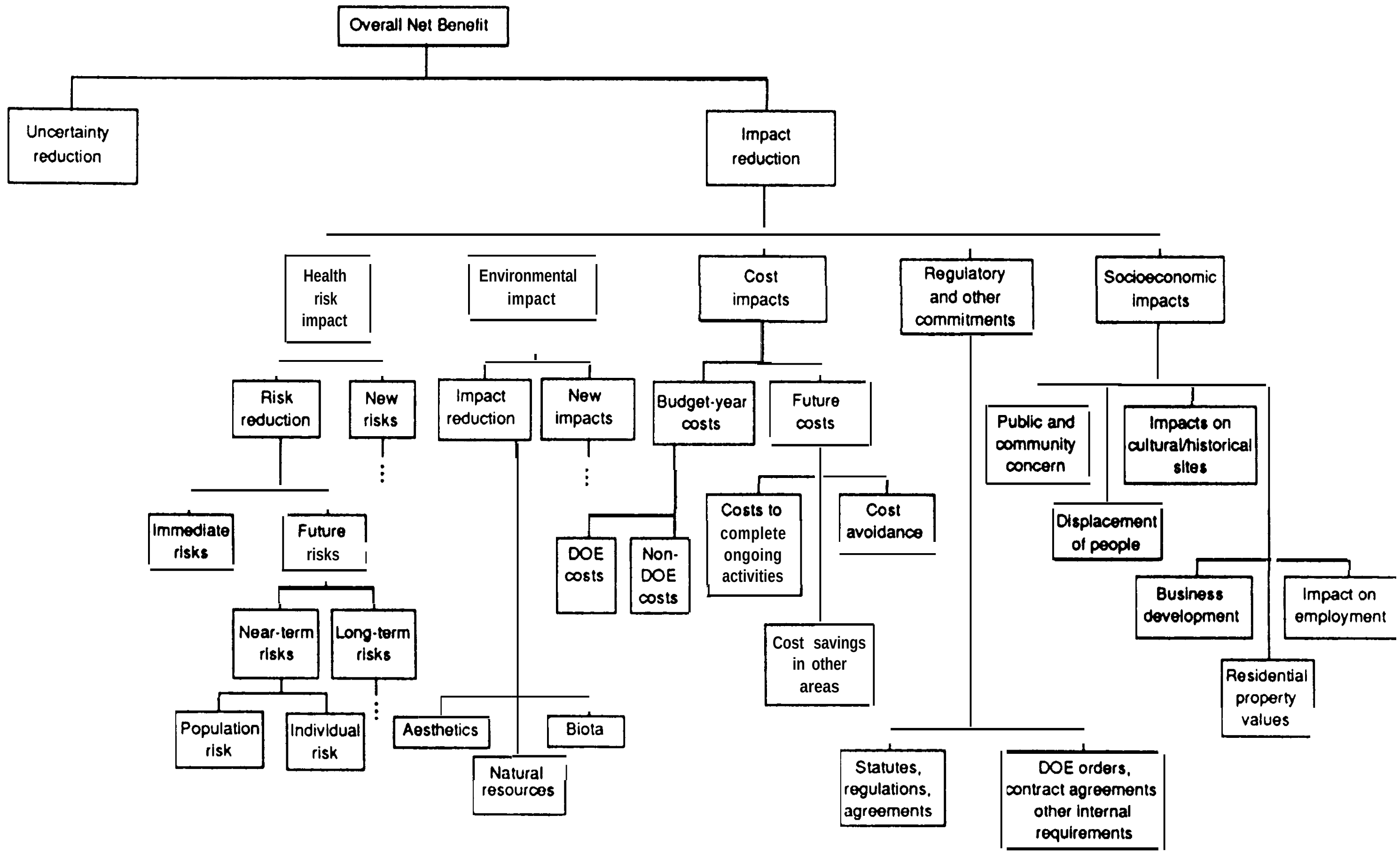
At the field level, each weapons facility is setting its own priorities for environmental restoration work, based on regulatory orders and agreements, as well as on that facility's understanding of urgent problems or needs. Thus, facilities that have negotiated and executed agreements with EPA or the States setting specific timetables for action have essentially already established many priorities for those sites. Some facilities (e.g., Hanford and Rocky Flats) have entered into very detailed agreements with specific schedules, whereas others have not begun to make such detailed commitments. Funding for these site-specific priorities, however, depends on the overall DOE budget allocation, and it is not clear how DOE will seek to modify existing agreements if adequate funding is not available in the future.

At the same time, DOE headquarters has been developing a separate "risk-based" priority system to help DOE "make budget decisions about how much funding to request for cleanup activities and how to allocate the funds that are made available" (34). This system will replace a similar, earlier one (the Program Optimization System) developed in response to congressional requests and will be applied initially only to environmental restoration activities. If the system proves useful and acceptable, DOE plans to extend the same general approach to waste management operations and to research and development. According to DOE, the "precise relationship of the steps in the priority system to the Five-Year Plan and the overall budget process is still evolving' (35). DOE has stated its intent to develop this method, which it contends is a "rigorous, risk-based prioritization methodology for application starting in FY 1992" (34).

The new priority system operation involves four phases. In the first phase-activity prioritization—the full range of activities that require funding at each facility for the budget year are to be identified as if full funding were available. The activities are then evaluated and assigned priority based on their ability to reduce uncertainty about the problems and consequences in five categories: health risk, environmental impact, cost impact, regulatory or other commitments, and socioeconomic impact. Figure 2-10 illustrates these categories. This phase is conducted primarily by DOE field offices.

In the second phase, also conducted by field offices, possible budget constraints are considered through the selection of sets of activities from the prioritized list to fit maximum, intermediate, or minimum budget levels. Then, in the third phase, the costs and benefits of each activity package (i.e., the sets of budget-yea activities focusing on a facility's problems) are determined. To accomplish this, field offices estimate the cost of each activity package and then assign a score for each of the five objectives

Figure 2-10-Proposed (Fundamental) Criteria for a Formal DOE Priority System Organized in a Hierarchy



NOTE:
Dashed lines below "New risks," "New Impacts,"and "Long-term risks" indicate subobjective structures similar to those shown under "Risk reduction," "Impact reduction," and " Near-term risks," respectively.

SOURCE: U.S. Department of Energy, Office of Environmental Restoration, "A Preliminary Conceptual Design of a Formal Priority System for Environmental Restoration," CDR Rev. 7 (Working Draft), May 1990.

used in the first phase, based on the package's ability to reduce impacts in these categories. After each activity package cost is estimated and the categories are scored, they are reviewed and, if necessary, revised by panels composed of representatives from all field offices and from headquarters.

Once the costs and "scores" of activity packages have been reviewed by the panel, a "multiattribute utility analysis" is applied to extract a single indicator of overall benefits for each package, along with an estimate of total package cost. The overall indicator of benefits is an aggregate of the objective scores resulting from this analysis, based on headquarters value judgments.

In the final phase, alternative budget levels are generated by using the estimated total costs and the indicators of package benefits. This phase is performed entirely by DOE headquarters using the formal priority system computer model. The multiattribute utility analysis model compares the costs and benefits of all the activity packages and calculates funding levels by evaluating different options for allocation of funds among field offices. The computer model also identifies the activity packages that can achieve or exceed regulatory and other objectives (those packages that offer the greatest benefits) at each funding level.

A different and largely unrelated effort by DOE's Environmental Safety and Health organization-the Environmental Survey[62]-attempted to develop a ranking system for environmental problems at DOE facilities. The system used multimedia transport models to project the potential for release of centaminants into the environment, the movement of contaminants through the environment to humans, and the risks to humans. The results of that survey are now being used as input to DOE's new quantitative priority system.

Evaluation

DOE's various priority systems have certain fundamental flaws and have yet to prove themselves useful in decisionmaking. The priority scheme used in the 1990 Five-Year Plan groups activities into four very broad categories. Most DOE activities fall into some portion of the first two categories (primarily, ongoing activities and compliance with interagency agreements). However, the scheme provides little or no guidance for ranking activities within those major categories (or indeed any category). In apparent recognition of this problem, DOE states that it is considering several different approaches to the priority system such as breaking down categories into sublevels.[63]

A different limitation pertains to priority 2—"those activities required to meet the terms of agreements (in place or in negotiation) between DOE and local, State and Federal agencies. " As noted in the 1990 plan, these agreements "represent legal commitments to complete activities on the schedules agreed to by DOE." If and when all the sites have entered into such agreements, the problem of funding all commitments simultaneously, along with other priority activities, will undoubtedly arise.

Federal regulators, the States, and many environmental organizations do not necessarily view these obligations as appropriate subjects for a priority system; rather, they believe that all commitments must be met and all regulations complied with. At the DOE Stakeholders' Forum[64] held in April 1990, several participants from environmental organizations were concerned that DOE was not requesting sufficient funds to meet all its commitments.[65]

In the 1990 Five-Year Plan (37), DOE's description of its new quantitative priority system and computer model states that reducing "health risk impact is of primary importance' and that "public health risk reduction and environmental protection'

62 The Environmental Survey was initiated to identify and prioritize existing environmental problems and risks at all DOE defense production sites. It was later expanded to include nondefense production sites. Preliminary results from defense sites were summarized in the "Environmental Survey Preliminary Summary Report of the Defense Production Facilities," released in September 1988. The final report is due in 1991.

63 One other alternative discussed in the Five-Year Plan is "to develop a ranking based on direct heal@ environmental, and regulatory risk'' (36).

64 DOE invited several dozen people reflecting a range of interests in the DOE Weapons Complex cleanup to a meeting called a ''Stakeholders Forum'' to review and discuss DOE's ''Predecisional Draft" of the 1990 Five-Year Plan. Participants in the 2-day forum (held at Airlie House, VA, in April 1990) were mainly from affected States, Indian Nations, Government agencies, and environmental, labor, and industry groups.

65 Although DOE has moved all "corrective activities" to priority 1, these relate primarily to bringing ongoing wastemanagement operations into compliance with environmental laws. Compliance with regulations under RCRA and CERCLA governing environmental restoration activities is still presumably covered under priority 2 by agreements. It is not clear that all such requirements are covered by agreements, however; those that are not will likely fall into priority 3.

Photo credit: Martin Marietta Energy Systems

Sediment samples are regularly taken in bodies of water impacted by the operations at Oak Ridge.

are "two factors of primary concern' in evaluating the utility of activities or projects (38). Yet, at present, the greatest uncertainty concerns the variables that should be given highest priority in these systems—reducing health and environmental risks. (See ch. 3 and app. D).

A major problem with any priority-setting scheme for cleanup is that credible data for most of the key parameters needed to evaluate proposed activities and assign priorities have not yet been obtained. It is not clear how DOE intends to address the uncertainties that now dominate the system's criteria, or what efforts will be made to develop a database for some critical factors such as specific information on each centaminated site within a facility, health and environmental risks from those sites, and lack of accurate cost estimates.

The priority systems could perhaps be used to identify categories of information that must be gathered in comection with key ranking factors (e.g., health or environmental impact) and to record any progress made in filling those data gaps over time. In fact, at this stage of the cleanup process, these may be the most useful applications of this type of system.

The methodology and model used in DOE's Environmental Survey (MEPAS-Multimedia Environmental Pollutant Assessment System), for example, has been criticized by the Natural Resources Defense Council (NRDC) on a number of grounds, including its failure to consider multiple contaminants or to identify the "most exposed individual, " as well as the lack of public involvement in its development.[66] The results of that MEPAS-based

[66] D. Reicher and J. Werner, Natural Resources Defense Council, testimony before the Senate Armed Service Committee, Subcommittee On Strategic Forces and Nuclear Deference, Apr. 7, 1989.

survey are among the only data available on site-specific risks from weapons plants, and the system did not begin to evaluate public health risks. The survey is nonetheless being used as input to the quantitative priority system being developed for application to DOE's environmental restoration (ER) budget. DOE recognizes the limitations of the Environmental Survey, which it describes as having "developed baseline information for some, but not all, of the problems covered by the ER program" (38).

Public involvement in the development and application of any DOE priority system is essential for its acceptance. The new quantitative priority system for environmental restoration activities may be too complex to obtain broad and meaningful public involvement. It is not yet clear whether effective public involvement will be achieved at each of the critical phases of this system, including those conducted by the field offices and finalized at DOE headquarters.

PUBLIC INVOLVEMENT

status

The foreword to the 1990 Five-Year Plan states that "through openness and cooperation, DOE hopes to make its environmental program more responsive to public concern' (39). In the 1989 Five-Year Plan (2), DOE outlined its public involvement efforts, which were directed primarily toward obtaining review and comments in connection with the plan. During development of the 1989 plan and after its publication, DOE invited input from the State and Tribal Government Working Group, which included representatives chosen by the Governors of 10 States, leaders of 2 Indian Nations, and representatives from the National Governors' Association, the National Association of Attorneys General, and the National Conference of State Legislators.

Recently, DOE has expanded the external review process to include several more States, another Indian Nation, and participants from a wider cross section of the public, including unions, industry associations, public interest groups, and environmental groups. In addition, as promised in the 1989 plan, a *Federal Register* notice invited public comment on the published plan.[67] DOE's responses to the comments are included in an appendix to the 1990 Five-Year Plan. In addition, DOE received input to that plan at the Stakeholders Forum held in April 1990. A "predecisional draft" was reviewed at this forum, which was attended by representatives from national environmental organizations, industrial and labor organizations, State governments, one Indian tribe, DOE, and other Federal agencies.

In response to a comment on the 1989 Five-Year Plan inquiring how State, tribal, and public participation will be implemented (and, specifically, what DOE means by public participation-whether groups will participate in the preparation of Activity Data Sheets submitted by the facilities, whether public hearings will be held, etc.), DOE noted that the "commitment to participation by States, Tribes, and the public is 'new culture' for DOE"; thus, details for accomplishing this will continue to evolve (40). DOE also noted that public hearings on the Five-Year Plan were not anticipated, but it specified other avenues for public participation: "Availability of plans for public comment, notice of intent to prepare environmental impact statements, and public scoping meetings are announced in the *Federal Register*. Public meetings near DOE facilities are advertised in area newspapers." DOE also stated that "defining public participation is difficult because the intent is to be inclusive, rather than exclusive, but limits to time, effort and budget must be recognized" (40).

The 1989 Five-Year Plan also called for public involvement in DOE's implementation of the plan at the operations office level. It states that affected parties should participate in the development and review of site-specific implementation plans. The 1990 plan does not indicate that this has come to pass. Although it acknowledges public involvement in the development of national plans (the Five-Year Plans and the Applied Research, Development, Demonstration, Testing, and Evaluation Plan (RDDT&E) (1,2,4)), it mentions local involvement only as something that is yet to come: "Beginning with this Plan, DOE will extend formal involvement to local communities near its facilities and sites. The mechanism for expanded public participation will be public participation plans for DOE's major installations, to be specified by Operations Offices in their

[67]Solicitation of Cements from the General Public on the Environmental Restoration and Waste Management Five-Year Plan, 54 Fed. Reg. 36372 (1989).

Site-Specific Plan'' (41). DOE anticipates more public involvement in the site-specific plans in the future (42).

The National Environmental Policy Act[68] and other environmental laws require public involvement in determining the scope and commenting on the analysis of weapons facility waste management and environmental restoration projects and alternatives. Pursuant to those requirements, the public has been invited to comment on certain environmental analyses prepared by DOE operations offices on specific waste management and environmental restoration projects. Several environmental organizations, led by the Natural Resources Defense Council, sued DOE, contending that it should be required to prepare a Programmatic EIS (PEIS) on weapons production, waste management, and environmental restoration at the Weapons Complex as a whole. In January 1990, Secretary James D. Watkins announced that DOE will prepare a PEIS for the Five-Year Plan (and a separate one on modernization of weapons production facilities) and will hold public meetings to obtain comments on the scope and content of that EIS (43). The series of 23 public scoping meetings began in December 1990 and is scheduled to continue in 1991 (44).

A final area in which DOE proposes to involve the public is the development of a priority system for the Weapons Complex. This system, described above, will serve as a replacement for the Program Optimization System—DOE's first quantitative priority-setting effort for environmental restoration. According to the 1990 Five-Year Plan, ''since last October, the External Review Group . . . has participated in the design of a rigorous, risk-based methodology for prioritizing remedial activities'' (45). Representatives from several States, Indian Nations, EPA, the Natural Resources Defense Council, and the Environmental Defense Fund are currently participating in the ERG.

Originally, six ERG meetings were planned between August 1989 and July 1990. Two were actually held during that period. After the second, members of the DOE-invited group stated their opposition to the current process because it limited, rather than encouraged, public involvement. DOE has since revised its approach and decided to hold

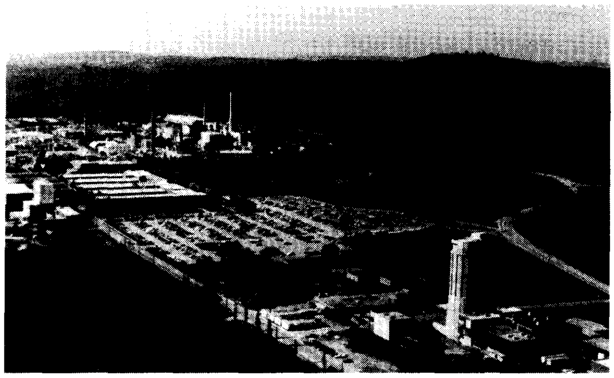


Photo credit: Martin Marietta Energy Systems

Aerial view of the Oak Ridge National Laboratory.

future meetings around a more developed concept while, at the same time, applying that concept to its budget process (46). A third meeting was held in September 1990, and members again expressed their frustration with the limited opportunity for input (47). These events or developments indicate that DOE appears to be having difficulty in effectively utilizing public input in this process.

At some DOE weapons facilities, advisory groups and committees that include representatives of community and environmental groups have been established. One such group is the FMPC Environmental Safety and Health Advisory Committee at Fernald. Committee members are appointed by the president of Westinghouse Materials Company of Ohio, the contractor at Fernald, and include scientific experts as well as representatives of the general public. According to the group's charter, its purpose is to provide ''independent assessment, evaluation and advice to the operating management relative to health and environmental issues, programs and policies.''[69]

There is also an advisory committee at Oak Ridge. In addition, DOE's Oak Ridge Operations Office is expanding its public involvement effort through its Environmental Restoration and Waste Management Office. That Office is responsible for developing and submitting to EPA a Community Relations Program Plan, based on EPA regulations and discussions with representatives from Oak Ridge and nearby communities. An implementation plan is also being developed, which is intended to provide opportunities for

[68]See supra note 6.

[69]FMPC Environmental Safety and Health Advisory Committee Charter, 1989.

public input, inform the public of planned and ongoing activities, and to focus and resolve conflict.

The implementation plan's objectives are being met through printed materials; DOE Oak Ridge officials are also preparing a newsletter that is being put in circulation through local newspapers. An "information resource center" has been set up in Oak Ridge to house documents relating to the Oak Ridge Reservation site activities as well as to Superfund, as required by EPA regulations. Future public meetings, workshops, and a speaker's bureau are also planned.[70]

Evaluation

Historically, the public has had great difficulty in obtaining information from DOE about environmental and health issues at the Weapons Complex. Many have been frustrated in their efforts to express concerns about these issues to DOE or to obtain satisfactory responses from DOE addressing those concerns. Recent DOE efforts outlined above have attempted to change this situation.

Throughout this study, OTA discussed public involvement issues with national and local public interest and environmental groups concerned with Weapons Complex cleanup. Many of these groups emphasized the need for additional and more aggressive efforts by DOE to involve the public in cleanup decisions. In addition, to obtain some impressions of how DOE's recent efforts are viewed by those actively involved with these issues—particularly at the community level-OTA staff had telephone interviews with 14 people from 10 citizen and environmental groups involved with cleanup issues at 8 sites across the Weapons Complex.[71] Through these interviews, OTA learned that all those interviewed were familiar with DOE hearings and comment periods. In general, representatives of most groups believe that certain individuals in DOE or with its contractors do make an effort to communicate more openly with the public. All were skeptical, however, about the existence of "a new culture, especially at the local level, and all expressed the view that, on the whole, DOE is still not actively seeking public involvement except in a few very specific instances. The problems outlined below contribute to this skepticism.

An issue cited in the conversations as fundamental to public involvement is public access to information. Conversations revealed continuing frustration over the difficulty of obtaining useful information from DOE. For example, no one gave a mainly positive response to the question, "Are you getting the information you need from DOE?" More than half of those interviewed emphasized the need to request desired information repeatedly. Most had experienced some level of success in making requests under the Freedom of Information Act,[72] but no one considered this a perfect, or even very satisfactory, way to obtain information. Representatives from four groups said that a noticeably longer time was required to obtain even routine environmental reports than before Admiral Watkins became Secretary of Energy, apparently because DOE headquarters wants to review information put out by field offices before making it available to the public.

Furthermore, although some public meetings or hearings held by DOE concerning individual sites were said to have gone well, every person interviewed expressed dissatisfaction with the way most meetings were conducted. Common complaints were as follows: the notification process is poor; meetings me held too late in the processes that they are supposed to inform; and information is presented so as to "intimidate' rather than inform the attending public. According to many, it is difficult, if not impossible, for people to track consideration of their comments. (In contrast, one person cited the Advisory Committee on Nuclear Facilities Safety, also known as the Ahearne Committee, as a group that sees its mission as involving the public and whose conclusions have clearly reflected public comments.[73])

70See "Environment Update, A Report from the Department of Energy on Environmental Restoration (ER) Activities at the Oak Ridge Reservation,'' Issue One, Oak Ridge, TN, September 1990.

71Interviews were held in July 1990 with representatives of the Concerned Citizens for Nuclear Safety; Energy Research Foundation; Fernald Residents for Environment, Safety, and Health; Greenpeace Action-Southeastern; Greenpeace USA; Hanford Education Action League (HEAL); Heart of America Northwest; Nuclear Safety Campaign, Snake River Alliance; and Tri-Wiley Citizens Against a Radioactive Environment (CARES). The sites with which these groups are directly concerned are Fernald, Hanford, INEL, LLNL, Los Alamos, Rocky Flats, Savannah River, and WIPP.

72Pub. L. No. 89-554, 80 Stat. 378 (1966) (codified as amended at 5 U.S.C. 552).

73Jason Salzman, Greenpeace USA, telephone conversation, July 13, 1990.

Representatives of two groups objected specifically to "workshops' at which DOE does essentially all the talking.[74] According to one, public attendance at these workshops is being used by DOE to "rationalize a level of community involvement that doesn't exist."[75] Another person cited the Stakeholders Forum to discuss the predecisional draft of the 1990 Five-Year Plan as a meeting that went well. However, he was not wholly satisfied, because, in his opinion, the meeting occurred too late to make any real difference in the plan.[76]

OTA's findings on the basis of these conversations are that DOE and the persons interviewed have very different perceptions of public involvement. Although DOE's recent efforts to involve the public are generally viewed as a step in the right direction, these efforts have yet to produce effective public involvement.

PLANS TO ENHANCE THE TECHNOLOGICAL BASE

Research and Development

General

DOE intends to develop and utilize new technologies in its environmental restoration and waste management efforts. The motivation for doing so is twofold: first, in many instances, technologies to accomplish certain cleanup and waste management tasks are either nonexistent or ineffective; second, implementation of new technologies is said to be able to significantly reduce future expenditures, especially with in situ treatment. These and other factors led DOE to state that "to successfully achieve its 30-year cleanup goal and to do this with the lowest possible cost, DOE must create and rapidly field new technologies concordant with all applicable regulations" (48).

The 1990 Five-Year Plan also calls for technological development spending related to site cleanup and waste management to increase from about $200 million in FY 1991 to $360 million by FY 1994-96. This represents 5 to 8 percent of the total cleanup budget projected for these years (8 percent currently, decreasing to 5 percent in 1995 and 1996). A new national program has been created for research and development; the organizational fiamework for such a program emerged in 1990 in the form of the new DOE Office of Technology Development (OTD). This program builds on past DOE research and development efforts including the Hazardous Waste Remedial Action Program (HAZRAP).[77]

DOE states in the 1990 Five-Year Plan that major research initiatives will focus on: 1) waste minimization, 2) improved waste operations to prevent the need for future site cleanup, and 3) environmental restoration to remedy past contamination. In addition, DOE intends to support major initiatives in education, training, and technology transfer. The 5-year budget allocates about 39 percent of technology funding for environmental restoration, 23 percent for waste operations, 10 percent for education, 13 percent for technical support, and 15 percent for program support (administration). Through this technological development program, DOE plans to make new, improved, and innovative technologies available for the most difficult environmental restoration and waste management problems.

OTD is addressing all major areas related to environmental restoration but is focusing particularly on new technologies for site characterization and monitoring because most current DOE activities are at this stage. In addition, DOE believes that new technologies could improve traditional well monitoring or laboratory sample analysis techniques that are costly and time consuming. DOE is cooperating with other agencies (e.g., EPA and the Department of Defense) in this effort, as well.[78]

The 1990 DOE plan proposes to increase funding; foster greater cooperation among national laboratories; implement a process for identifying the best technologies; develop a rigorous, consensus-based prioritization methodology for research and devel-

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74 Marylia Kelley, Tri-Valley CARES, telephone conversation, July 9, 1990; Jim Thomas, Hanford Environmental Action League, telephone conversation, July 6, 1990.

75 Marylia Kelley, Tri-Valley CARES, telephone conversation July 9.1990.

76 Tim Connor, Energy Research Foundation telephone conversation, July 9, 1990.

77 HAZRAP consists of the Hazardous Chemical Waste Research and Development Program and the Technology Demonstration Program. With funding from DOE headquarters, the objective of these programs is to promote and expedite technological research, development, and demonstration relevant to RCRA, CERCLA, and SARA.

78 Thomas Anderson, Physical Scientist, Office of Technology Development, DOE, letter to Peter Johnson, OTA, July 16, 1990.

opment activities, with public participation; promote specific technologies for specific purposes; and implement new educational initiatives. DOE intends to support new university consortia and degrees relevant to its needs, as well as proposals encouraging students to specialize in vital areas. These actions in education respond to DOE's concern about a shortage of skilled personnel in areas required for cleanup.

The new Office of Technology Development is one of three separately funded entities in the Office of Environmental Restoration and Waste Management, created to provide a closer link between needs and research projects. During 1990, substantial efforts were devoted to putting these new organizations in place, holding meetings, or starting educational initiatives. DOE claims that its program of technological development will help achieve its 30-year cleanup goal at the lowest cost. DOE has made only rough estimates of the benefits (in the form of decreased costs, risks, and time required for completion) that may result from aggressive technological development. However, it claims that such benefits will be substantial and that without such a program, exorbitant costs, probable delays, and unnecessary exposure of workers and the public to chemical or radiological hazards will result. DOE expects a major return from its investment of about $1 billion in technological development over the next 5 years (49).

Selecting Projects

DOE has established a process within OTD to select the most promising technologies for developmental support.[79] For example, the In Situ Remediation Committee, consisting of DOE contractor technical personnel, will review the large number (about 1,000) of proposals received by DOE from field offices and prepare a report recommending specific technologies for funding. In the course of its evaluations, the committee will develop a checklist of criteria to be used in evaluating proposals. DOE's Office of Environmental Restoration will participate in a "validation' meeting to provide input on specific environmental restoration needs. Also, the contractor committee will assist the DOE program manager for in situ remediation.

DOE has also emphasized cooperation among field offices on technical projects. Although technological development has been reorganized and budget increases have been projected, work on disposal and remediation technologies has been underway at DOE for some time (e.g., in situ vitrification). There does, however, appear to be movement toward closer cooperation among personnel in field offices working on similar technical projects, as well as in defining projects that involve more than one field office (e.g., the integrated demonstration of directional drilling with air injection at the Savannah River Site). Finally, DOE seems to be looking toward more cooperation with both the private sector and other Government agencies in technological development, including EPA's Superfund Innovative Technology Evaluation (SITE) program.

Cleanup Technologies: State of the Art

With a few notable exceptions, the state of the art in nuclear and hazardous waste management and cleanup is primitive. The exceptions, such as the Defense Waste Processing Facility for vitrification of high-level waste at Savannah River, tend to be technologies that DOE has taken a long time and spent a great deal of money to develop (16). In environmental restoration, DOE has adopted a similar approach with respect to in situ vitrification, in which it has invested about $15 million and a decade of developmental work so that today the technology can begin to be field-tested for immobilization of certain contaminated soil sites (see box 2-K). Another recently developed technique that DOE has begun to test at sites such as Savannah River and INEL is vapor vacuum extraction. This commercially developed technique entails pumping and suctioning shallow underground wells to extract volatile organic contaminants from the soil.

Evaluation

Although many problems at the weapons sites are still in need of solutions, practically all new ideas in cleanup technology are in the very early stages of development. DOE should plan for a long-range commitment of time and money to the development of new technologies if it is to bring them to the stage at which they can be applied at weapons plants. A well-thought-out strategy is required for bringing the most promising technologies into the field.

[79] This process was discussed with DOE officials at an OTA Workshop on Remediation Techniques, May 8, 1990.

Box 2-K—Development of In Situ Vitrification (ISV) Technology

Types of Technology: Thermal treatment of near-surface soils, sludge, and other contaminated materials in place by using electrodes that heat up to 2,000 ° Celsius, thus melting the material and later solidifying it into a glasslike form. A hood with filters is used to capture the off-gasses. The process is reported to destroy organics and immobilize certain metals and radionuclides.

Developmental Highlights: Development began at DOE in 1981, based on electric melter technology for high-level waste. Initial work was performed at Battelle's Pacific Northwest Laboratory at Hanford. Thirty-six laboratory, engineering, and pilot tests were conducted from 1981 to 1986. A patent was issued to DOE in 1983 for the process, and DOE later granted the rights to Battelle. Several large-scale tests were run through 1988 when Battelle created a separate company (Geosafe, Inc.) to commercialize the technology.

Funding: DOE has invested about $15 million on ISV development to date. Current (FY 1990) funding is about $4 million.

Status: In 1990 a full-scale demonstration test was conducted on a mixed radioactive and hazardous waste site at Hanford; the results are being analyzed. Other DOE sites have run smaller-scale tests on inert material. Geosafe intends to use the technology for a commercial application at a Superfund site in 1990 or 1991. The technology still has a number of limitations (melt depth and dimensions, water table instability, collection of effluents) and requires further development to make it more widely applicable.

Application: This technology appears to be suitable for remediation work at certain sites where contaminated near-surface soils or burried waste can be treated in-place. Determination of applicability would include considerations of waste types, amount of moisture present, cost of electricty, ability to contain off-gasses, and dimensions of contamination.

Lessons Learned: Technology that has a variety of applications to critical DOE remediation work and that can benefit from related developmental efforts has a good chance of success if it receives substantial, consistent support over a long time period. That support would include a competent work force as well as funding. A successful developmental process must also allow for creativity, flexibility, and learning from problems encountered.

SOURCE: Office of Technology Assessment, with information developed at May 8, 1990, Technology Workshop.

As part of DOE's technological development program, it will be important to identify the greatest needs and the areas in which new technology can make a difference. The first step should be to identify cleanup needs and to determine those that are most urgent and serious. In this step, information about health effects should be factored in as it becomes available. For example, among the problems that DOE has already identified as particularly intractable are the following (see apps. A, B, C and ref.16:

- groundwater centarnination at almost all sites,
- plutonium in soil (e.g., at Rocky Flats and Mound Plant),
- silos containing uranium processing residues at Fernald,
- single-shell tanks containing high-level waste at Hanford, and
- buried transuranic waste at INEL.

After determining those problems most in need of solution, DOE could identfy the technologies that are most likely to address key needs and investigate the alternatives that can be developed for each key problem, together with the relative costs and benefits of these alternatives. This identification of needs, followed by an analysis of alternative technological approaches, should be a continuous process that feeds in new characterization data as well as information on health and environmental effects as they become available.

If DOE is going to develop advanced technical solutions, however, it will have to be realistic about the effort, time, and funds required. Many projects could require at least the level of effort devoted to in situ vitrification over the past 10 years. Considerable effort must be given to the demonstration, testing, and evaluation phases of technology development. If a new technology does not perform as expected under particular field-test conditions, the results should not necessarily be viewed as a failure. Rather, early problems can provide opportunities to improve a technology and develop appropriate applications.

In some instances, however, not enough is known to solve a problem—e.g., groundwater remediation.

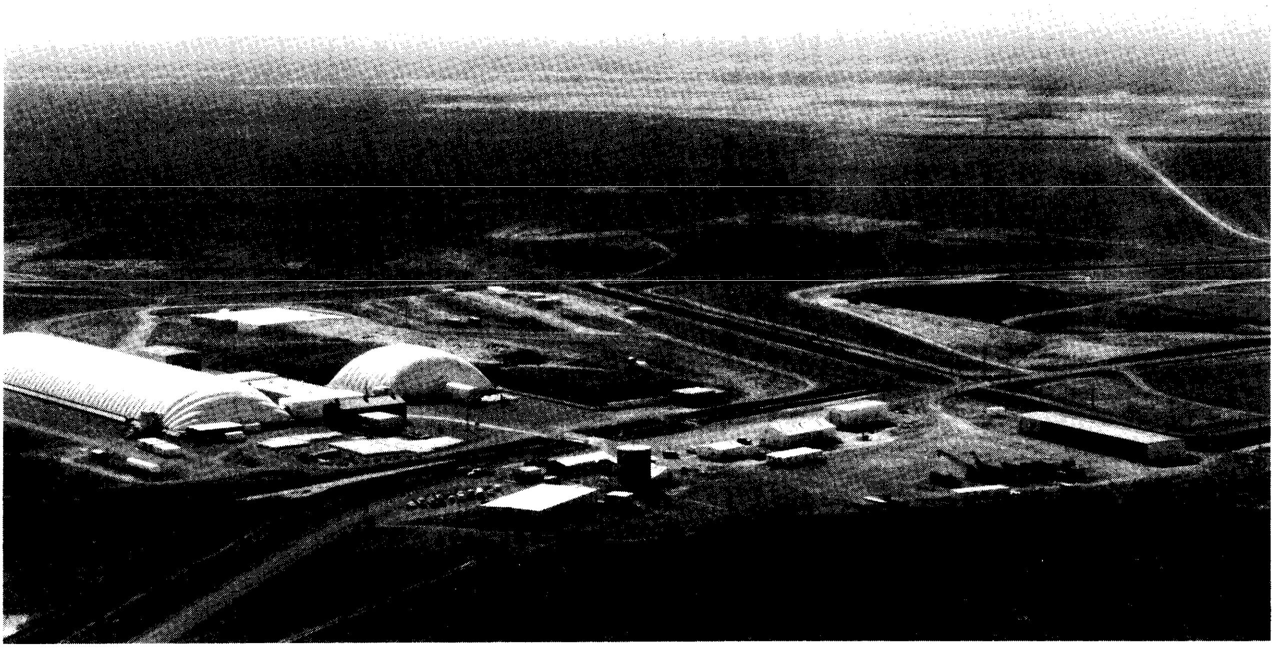

Photo credit: U.S. Department of Energy

Radioactive Waste Management Complex where a number of new technologies will be tested at INEL.

The best approach in this case maybe not to spend a great deal of money attempting to develop new approaches, but rather to contain and monitor centarnination, to apply state-of-the-art technology at each place groundwater centamination is found, and to learn about the successes, failures, and appropriate applications of this technology. In some cases, it may not be feasible to clean up an aquifer but instead to rely on point-of-use treatment.

Although investing in technology is never a sure thing, a program that is too diverse and scattered among research projects may not bean effective way to solve the problems existing at weapons plants. What is needed is a process that will devote adequate sums of money and concentrated efforts to focused technological development, rather than spending a little money for many items on a long "wish list."

DOE has taken the necessary first step by establishing a headquarters organization devoted entirely to technological development. That organization can conduct the analyses required. First, however, it must overcome a problem inherent in DOE's current 5-year planning approach-i. e., taking the amount of money expected to be available for 5 years and estimating the projects that can come out of that amount, rather than determing what really needs to be done to solve key problems and what can be accomplished toward that objective during the 5-year period.

The OTA workshop held in May 1990 focused on: 1) defining the status of existing and forthcoming remediation technologies that may be applied to DOE's environmental restoration program and 2) understanding the benefits and limitations that can be expected from their use.

Participants noted that although much work has been devoted to research, development, and testing ofremediation technologies, few real "breakthroughs" have occurred over the last 10 years either within DOE or in the private sector. (The only significant ones noted by participants were in situ vitritication and vapor vacuum extraction.) The reasons listed below were cited as possible contributors to what was viewed as an overall lack of major progress:

- *Insufficient Numbers of Trained Personnel*— Good management of remediation efforts requires individuals with multidisciplinary aca-

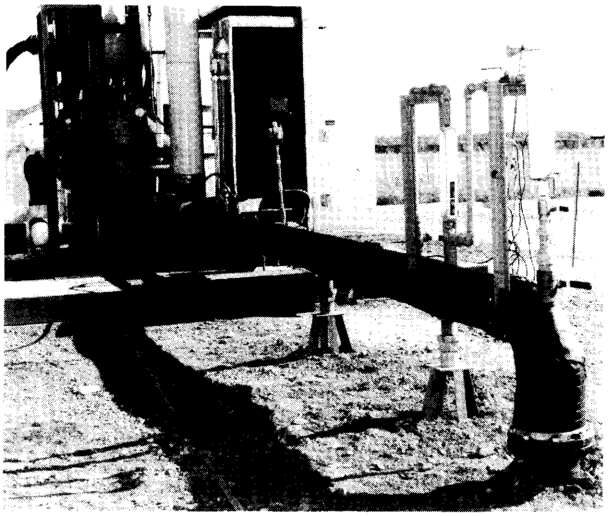

Photo credit: U.S. Department of Energy

Vapor vacuum extraction demonstration at INELto remove hazardous organic vapors including carbon tetrachloride from below the Radioactive Waste Management Area.

demic and professional backgrounds. Better communication among disciplines is also needed. Expanded support for academic and training programs is essential.

- *Lack of Feedback From Characterization and Remediation to Research—A* key requirement is a connection between research and characterization or remediation efforts. Initial remediation efforts should be subject to postmortems to assess their effectiveness and provide guidance for further research; site characterization should also be reviewed systematically.
- *Lack of Prioritiescorrelative Levels of Funding—* Very few developmental efforts have received consistent, substantial support focused on clear goals. There is a need to set priorities for the development of new technologies (i.e., to identify those with the most promising potential solutions for problems at hand), so as to allow the most effective allocation of funds.
- *Tendency To Seek "Quick Fixes'' -It* is generally beneficial to consider the use of interim remedies to gain time for the development of more effective solutions, rather than to proceed with expedient—but often inadequate—solutions. Most remediation problems are very complex and require the application of a wide range of skills over a long period.

DOE has indicated that it favors in situ remediation technologies as a means of reducing the cost of environmental restoration. There is a general sense within DOE that in situ technologies could lead to savings, particularly because removal and treatment technologies usually involve handling and processing large quantities of material (50). However, in situ technologies in general require substantial development before they can be applied widely to cleanup problems. Biological and chemical in situ techniques involve introducing agents into soil or groundwater so that they come in contact with contaminants and react with them; these techniques, however, do not affect radionuclides. Other techniques such as in situ vitrification serve to immobilize and contain the pollutants (including radionuclides) in place. Because knowledge of the location, concentration, and movement of contaminants is difficult to obtain, the effectiveness of in situ techniques is doubly difficult to assess. For example, bioremediation has progressed farthest as a system to treat contamination in surface bioreactors, rather than underground where there is great uncertainty about its effectiveness. Substantial research and characterization will be necessary to reduce this uncertainty (see app. B).

Education

There seems to be general agreement that the number of individuals and the level of expertise required for DOE's cleanup efforts are inadequate. A shortage of necessary skills exists at all levels. Human resource availability and skills in weapons production do not necessarily translate into availability and skills for environmental restoration.

In the 1990 Five-Year Plan, DOE points out that environmental restoration and waste management activities require a relatively high level of expertise and that skilled professionals are in short supply. Furthermore, the competition for critical skills is likely to intensify among DOE, EPA, State agencies, and private contractors.

DOE intends to implement new and expanded educational support programs focused on helping meet its critical personnel requirements for the future. Initial steps include pilot programs for DOE and university partnerships, as well as fellowship or scholarship programs to draw students into environmental careers. DOE's plan calls for an expansion of innovative outreach programs to minorities and to the educationally disadvantaged (4).

Two pilot DOE-university partnerships have been established, one involving three universities in New Mexico and the other involving four universities and colleges in South Carolina. In New Mexico, a Waste Management Education Research Center was established to offer master's degrees in several engineering fields, with emphasis on environmental restoration and waste management. In South Carolina, in addition to curriculum modifications the partnership will emphasize applied research closely connected with environmental restoration and waste management issues at the Savannah River Site.

DOE's budget in the 1990 Five-Year Plan for education and outreach is about $21 million in FY 1991, increasing to $37 million by FY 1994. Clearly, an educational initiative is needed that, given consistent support, should significantly enhance the pool of talented professionals available to resolve future environmental problems. Most experts agree that human resources are as critical as financial resources in solving contamination and waste problems at the Weapons Complex. It would also be wise to monitor the DOE educational program for some later analysis of its accomplishments. Although DOE has emphasized support for educational initiatives, it has not specifically analyzed its needs for a future environmental work force, in terms of either numbers, a timetable to meet cleanup goals, or a breakdown of the required disciplines.

Reducing Future Waste

DOE has emphasized the role of waste minimization in several of its planning documents for defense waste management and environmental restoration. For example, in the 1989 Five-Year Plan, DOE stated that it will focus resources on three major classes of activity, one of which is to ". . continue safe and effective waste management operations but emphasize systematic minimization of waste generation" (51). In the 1989 Draft Applied Research, Development, Demonstration, Testing and Evaluation Plan, DOE stated, "Waste minimization, the reduction in the generation of radioactive, hazardous, and mixed waste *before* treatment, storage, or disposal, is a legal requirement, an ethical responsibility, and often a financial benefit. DOE will make waste minimization a key factor, not only in process and facility modification but also in the procurement of goods and services. The major new modernization goal of minimizing waste generation entails a significant RDDT&E component" (52). Recycling is stated to be another major initiative associated with waste minimization. DOE's stated goal is to achieve a 60 to 80 percent reduction in waste generation (FY 1985 baseline) within 10 years of program initiation by material substitution, process alteration, new production hardware, and recycling. Planned programs include demonstration of minimization methods for plutonium and enriched uranium, hazardous material substitution, and material reclamation from old burial grounds (4).

Preliminary DOE estimates indicate that waste minimization could result in a significant reduction of waste treatment, storage, and disposal costs, as well as a reduction in worker exposure and public risk. According to DOE, waste minimization will affect all present and proposed DOE operations and the agency is now moving to a more formal program from an ad hoc approach in the past (53). A formal cost-benefit analysis of waste minimization is planned during FY 1990-91 by using EPA waste minimization cost-saving methodology (54).

Efforts to develop a focused waste minimization program at DOE are new, having been initiated in early 1989 when DOE established a Waste Reduction Steering Committee (54). This committee has made a series of site visits to review waste generation and packaging operations, to review methods and technologies, to develop methods of reporting, and to develop guidance and requirements. The site visit reports summtie waste reduction activities at these facilities-waste *reduction being* defined in the January 1989 guidance establishing the committee as waste *minimization plus treatment to reduce* either the *volume* or the *toxicity* of waste requiring disposal (55). Four waste reduction workshops have been held during the past 2 years. The committee also hopes to help infuse the waste minimization philosophy into production or modernization planning and decisions.

DOE has drawn several conclusions from the site visit reports:

1. Sites are now very aware of waste minimization concepts and requirements.
2. Many waste minimization projects have been implemented that require little funding and minor technical changes.
3. Many sites have implemented charge-back systems to reward waste minimization efforts. Award fees are also being used to reward contractor waste minimization efforts.

4. High-level and transuranic waste minimization efforts have not been given sufficient attention and emphasis.

DOE lists accomplishments at the visited sites as implementing training programs, performing surveys and audits, achieving substantial source reductions of hazardous waste through substitution and administrative controls, and recycling. Promising areas for future activity include recycling and reuse, administrative controls to segregate wastes and avoid generation of low-level or mixed waste, substitution of nonhazardous for hazardous materials, and process improvements to enhance efficiency or eliminate hazardous waste streams. The last is said to require careful analysis and long lead times (54).

DOE characterizes waste minimization efforts as at a relatively early stage, with staffing and funding a year or two away from full program implementation levels. The design of a hypothetical new plant (e.g., a new plutonium recycling plant at Rocky Flats) incorporating the best methods to minimize waste generation is projected to require a 1-or 2-year effort by a design team (54).

The amount of effort currently devoted to waste minimization is not yet commensurate with the importance DOE attaches to that activity in its principal planning documents. However, if DOE follows through in its stated commitment to waste minimization, a major shift in program emphasis should occur over the next few years.

DOE's waste minimization efforts are less than 2 years old. A comprehensive waste minimization plan is expected to be in place in 1991. A very small staff is currently assigned to waste minimization at DOE headquarters. Organizationally, waste minimization has had relatively low status in the DOE bureaucracy, both in the field and at headquarters. These factors should all change markedly as DOE institutes its new waste management philosophy.

Although OTA has not verified DOE claims for the benefits of waste minimization, the potential for meaningful cost savings and other cleanup advantages is real. This appears to be particularly true in the hazardous waste area, where administrative directives and substitution of nonhazardous materials could have positive effects.

Care should be taken to avoid labeling as waste minimization those actions that are driven primarily by regulatory requirements but do not actually reduce the total amount of waste generated. An example of this is the segregation of hazardous and radioactive components to reduce the amount of mixed waste. Although the latter is currently difficult to store or dispose of because of the EPA land ban and the lack of approved treatment, such segregation does not address the physical reality that a certain amount of hazardous and radioactive material still must be dealt with.

Although some significant reductions in waste generation may be expected from relatively inexpensive measures such as instituting administrative controls on the use of hazardous materials, larger gains are likely to require a substantial increase in resources and commitment if production is maintained and the Weapons Complex is gradually modernized. In particular, the design of new facilities that generate less waste requires a significant increase in both the resources and the personnel devoted to process design and modification.

Getting the production side of DOE to take waste minimization seriously is important if such efforts are to succeed. Waste minimization should be incorporated into the design philosophy for plant modification and new construction. Expanded efforts to create this atmosphere within DOE Defense Programs would yield substantial benefits.

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