GAO

United States General Accounting Office

Fact Sheet for the Chairman, Environment, Energy, and Natural Resources Subcommittee, Committee on Government Operations, House of Representatives

November 1989

NUCLEAR WASTE

DOE's Program to Prepare High-Level Radioactive Waste for Final Disposal

GAO/RCED-90-46FS

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-231294

November 9, 1989

The Honorable Mike Synar
Chairman, Environment,
Energy and Natural
Resources Subcommittee
Committee on Government Operations
House of Representatives

Dear Mr. Chairman:

This fact sheet responds to your September 22, 1988, request for information on the Department of Energy's (DOE) program for immobilizing high-level radioactive waste.[1] As agreed with your office, we are providing information on the quantities of waste, immobilization approaches, and estimated costs for DOE's four waste immobilization projects--the Savannah River Site in South Carolina, the West Valley Demonstration Project in New York, the Hanford Site in Washington State, and the Idaho National Engineering Laboratory (INEL) in Idaho.

In summary, as of December 1988, the four sites collectively stored about 95 million gallons of high-level waste in underground tanks and bins.[2] Approximately 57 million gallons are stored at Hanford, 34 million gallons at Savannah River, 3 million gallons at INEL, and .6 million gallons at West Valley. The waste is in several forms, including liquid, sludge, and dry granular materials, that make it unsuitable for permanent storage in its current state at these locations. Leaks from the tanks, designed for temporary storage, can pose an environmental hazard to

---

[1]"Immobilization" describes the conversion of high-level waste into a solid form that is suitable for permanent disposal.

[2]About 57 million gallons of this waste is currently scheduled to be immobilized. A decision on the remaining waste will be made when an environmental impact statement is completed in 2002. This waste is the subject of a GAO report: Nuclear Waste: DOE's Management of Single-Shell Tanks at Hanford, Washington (GAO/RCED-89-157, July 18, 1989).

surrounding land and water for thousands of years. DOE expects that when its waste processes at Savannah River, West Valley, and Hanford become operational, the high-level radioactive waste stored at these sites will be blended with other materials to immobilize it by forming a glass-like substance. The glass form will minimize the risk of environmental damage and make the waste more acceptable for permanent disposal in a geologic repository. At INEL, DOE is still considering various other immobilization and permanent disposal approaches.

In July 1989, DOE estimated that it would cost about $13 billion (in fiscal year 1988 dollars) to retrieve, process, immobilize, and store the high-level waste until it can be moved to a permanent disposal site: about $5.3 billion is expected to be spent at Savannah River, $0.9 billion at West Valley, $2.8 billion at Hanford, and $4.0 billion at INEL.[3]

As shown in table 1, immobilization of the waste accumulated at the four sites could take from 2 to 17 years.

Table 1: DOE's Planned Construction and Processing Schedules for High-Level Waste Immobilization Facilities

Activity	Savannah River	West Valley	Hanford	INEL
Construction starts	1983	1983	1991	2002
Immobilization starts	1992	1996	1999	2011
All accumulated wastes immobilized[a]	2008	1998	2008	2028
Future wastes immobilized	Yes	No	Undecided	Yes

[a]Includes all high-level waste that exists as of the date immobilization begins.

---

[3]According to DOE, these estimates do not include costs such as the transportation of the immobilized waste to the repository, the disposal fee charged, near-surface disposal of low-level wastes resulting from pretreatment of high-level waste, or decontamination and decommissioning costs for the immobilization facilities. (See sec. 1.)

DOE has started construction at Savannah River and West Valley for facilities that will be used to transform the waste into glass (a process known as vitrification). These sites have each encountered schedule delays, and one has encountered a significant cost increase over earlier estimates. More specifically,

-- The Savannah River facility is scheduled to begin high-level waste vitrification in 1992, about 2 years behind the schedule established in late 1983. The current cost estimate to bring the facility on-line appears very close to an estimate made in 1984. (See sec. 2.)

-- The West Valley project, based on a January 1989 estimate, is scheduled to begin high-level waste vitrification in 1996, about 8 years later than the schedule established in early 1984, and the cost could be about $1.1 billion, more than double the 1984 cost estimate. According to a DOE official, if the recently released 5-year plan is fully implemented, the cost could be reduced to about $890 million. (Both estimates are in year-of-expenditure dollars.)

DOE has plans for immobilization facilities at the other two sites, but unresolved issues could affect the reliability of current cost and schedule estimates. For example,

-- The Hanford facility, currently in the design phase, has an estimated immobilization completion date of 2008, but this date assumes that (1) Hanford's defense mission nuclear processing activities will end in the mid-1990s and (2) only the waste stored in Hanford's double-shell tanks will be immobilized. It is uncertain how much, if any, of the site's 37 million gallons of radioactive waste stored in 149 underground single-shell tanks will require vitrification. DOE does not expect to make a decision on this issue until about 2002.

-- The INEL facility is currently in such an early planning phase that DOE has not yet selected the waste immobilization technology that it will use. The waste may be transformed into a glass-ceramic or other material instead of being vitrified. DOE expects to make this decision in 1993.

Section 1 contains an overview of DOE's high-level waste immobilization program. Sections 2 through 5 contain more detailed information about each of the four projects.

- - - -

For this fact sheet, we interviewed or obtained information from engineers and managers working at DOE headquarters; its operations offices at Richland (Hanford), Savannah River, and Idaho; and its West Valley Project Office. We also reviewed DOE reports, correspondence, and studies pertinent to each project covering such topics as the projects' history, immobilization processes, waste characteristics, schedule, and cost estimates. We did not evaluate the accuracy of cost estimates provided to us by DOE.

We provided a statement of facts to DOE officials for their review. DOE generally agreed with our statements but suggested clarifications, which we incorporated, where appropriate, in this report. As requested, we did not obtain official agency comments on this fact sheet. We performed our work between September 1988 and July 1989.

As arranged with your office, unless you publicly announce its contents earlier, we will not distribute this fact sheet further until 30 days after the date of this letter. At that time we will send copies to the Secretary of Energy, appropriate congressional committees, and other interested parties. If you have any questions, please call Victor S. Rezendes, Director, Energy Issues, who may be reached at (202) 275-1441. Major contributors to this fact sheet are listed in appendix I.

Sincerely yours,

Keith O. Fultz
Director of Planning
and Reporting

CONTENTS

ABBREVIATIONS

DOE	Department of Energy
DWPF	Defense Waste Processing Facility
GAO	General Accounting Office
HWVP	Hanford Waste Vitrification Plant
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory
NFS	Nuclear Fuel Services, Incorporated
NRC	Nuclear Regulatory Commission

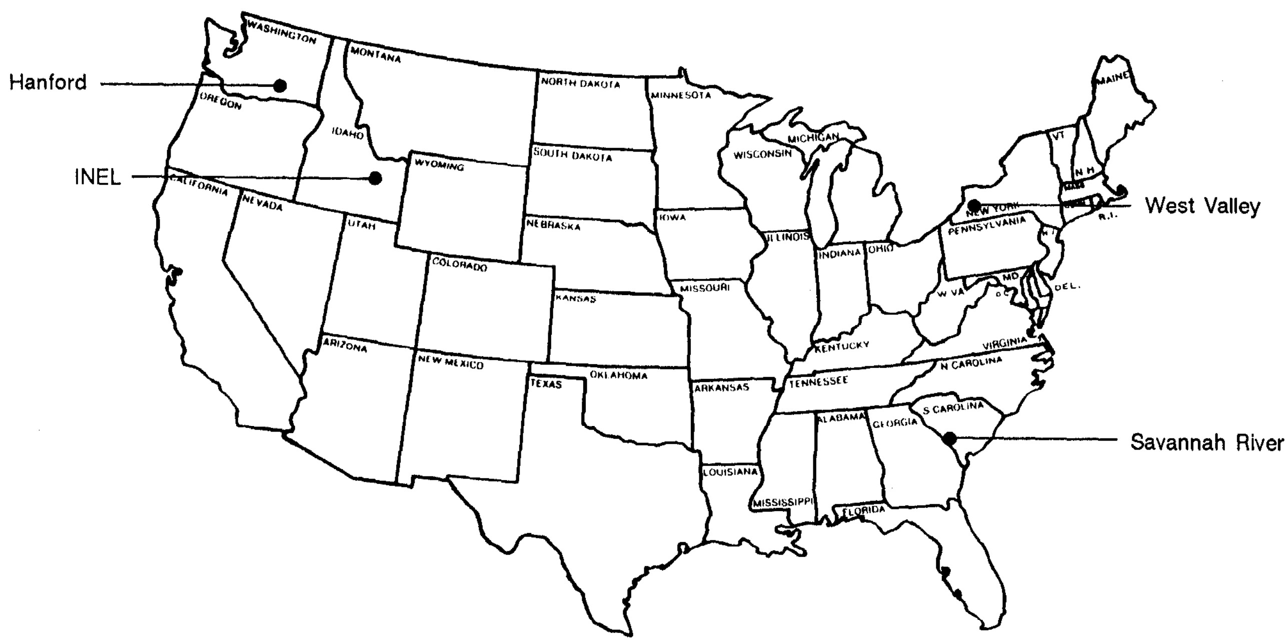
SECTION 1

OVERVIEW OF DOE'S HIGH-LEVEL

WASTE IMMOBILIZATION PROGRAM

Since the early 1940s, the Department of Energy (DOE) and its predecessor agencies have been generating high-level radioactive waste.[1] This waste, generated mainly from reprocessing used ("spent") nuclear fuel for DOE defense production activities, is stored in underground tanks or bins at three locations--Savannah River, Hanford, and the Idaho National Engineering Laboratory (INEL). A fourth high-level waste storage location--West Valley--is the site of a commercial reprocessing facility that ceased operation in 1972. In 1980, the Congress directed DOE to solidify West Valley's high-level waste.

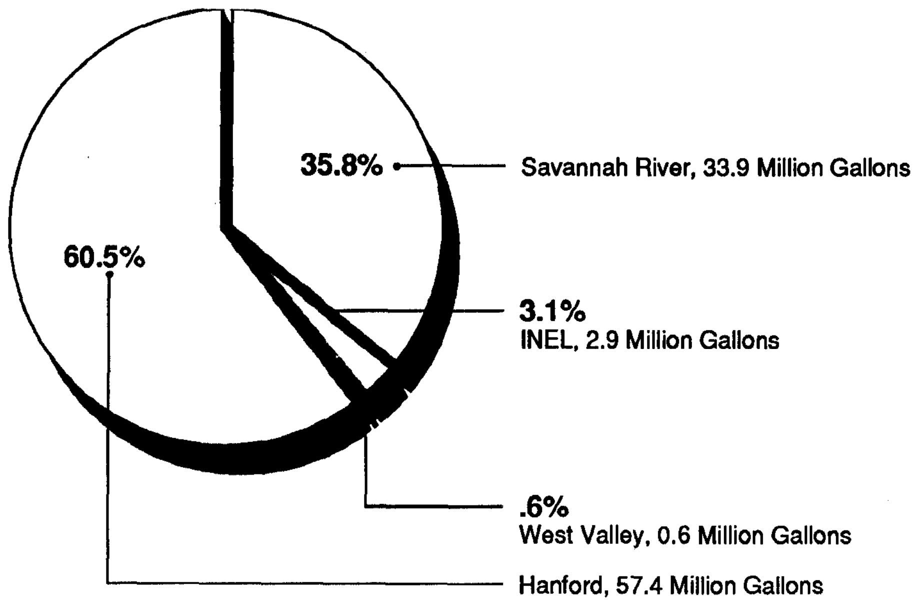
Figure 1.1: Location of DOE's High-Level Waste Management Facilities



[1]According to DOE, high-level waste includes the liquid from nuclear fuel reprocessing, and any solid derived from the liquid, that contain a combination of transuranic waste and fission products in concentrations that require permanent isolation from the environment. Transuranic wastes contain man-made radioactive elements having atomic numbers greater than uranium. Fission is the splitting of the nucleus of an atom--the basic process by which nuclear energy is released.

In December 1988, the four locations had about 95 million gallons of high-level waste stored in underground tanks and bins, including about 37 million gallons in Hanford's single-shell tanks. As indicated in figure 1.2, approximately 91 million gallons (about 96 percent) of this waste is stored at Hanford and Savannah River.

Figure 1.2: Distribution of DOE's High-Level Waste Volume



Note: Figures based on December 1988 data.

DOE's high-level wastes emerge from spent nuclear fuel processing as an acidic, highly radioactive, and heat-producing liquid. The wastes are then treated for storage and placed in underground tanks. During years of storage, some of the liquid waste has changed or been changed into one of several solid forms, including sludge, saltcake, and a dry granular material.[2] Waste treatment and waste form differ by site, but regardless of the form, some of the waste remains dangerous for thousands of years.

Savannah River, Hanford, and most of West Valley's wastes are converted from acid to an alkaline solution to prevent corrosion of the carbon steel storage tanks. Changing the liquid waste to an alkaline solution causes solids to settle, creating a layer of sludge; a saltcake layer is created by evaporating the liquid portion of the waste.

INEL's acidic liquid wastes are not converted into an alkaline solution but are solidified into a dry granular solid

---

[2]As discussed in section 4, Hanford also stores encapsulated cesium and strontium that was separated from high-level waste.

called calcine. The calcine is stored in underground stainless steel bins contained within concrete vaults.

DOE'S APPROACHES TO IMMOBILIZING ITS HIGH-LEVEL RADIOACTIVE WASTES

In the early 1980s, DOE initiated efforts to end the interim storage of its high-level radioactive waste by developing plans to immobilize and ship it to a geologic repository for permanent disposal. Like many other nations, including England, West Germany, Japan, and France, DOE selected vitrification--a process that immobilizes the high-level waste by turning it into glass. DOE has selected vitrification for three of its sites. For the fourth site (INEL), DOE is examining other processes that may be more appropriate for immobilizing the site's calcined waste.

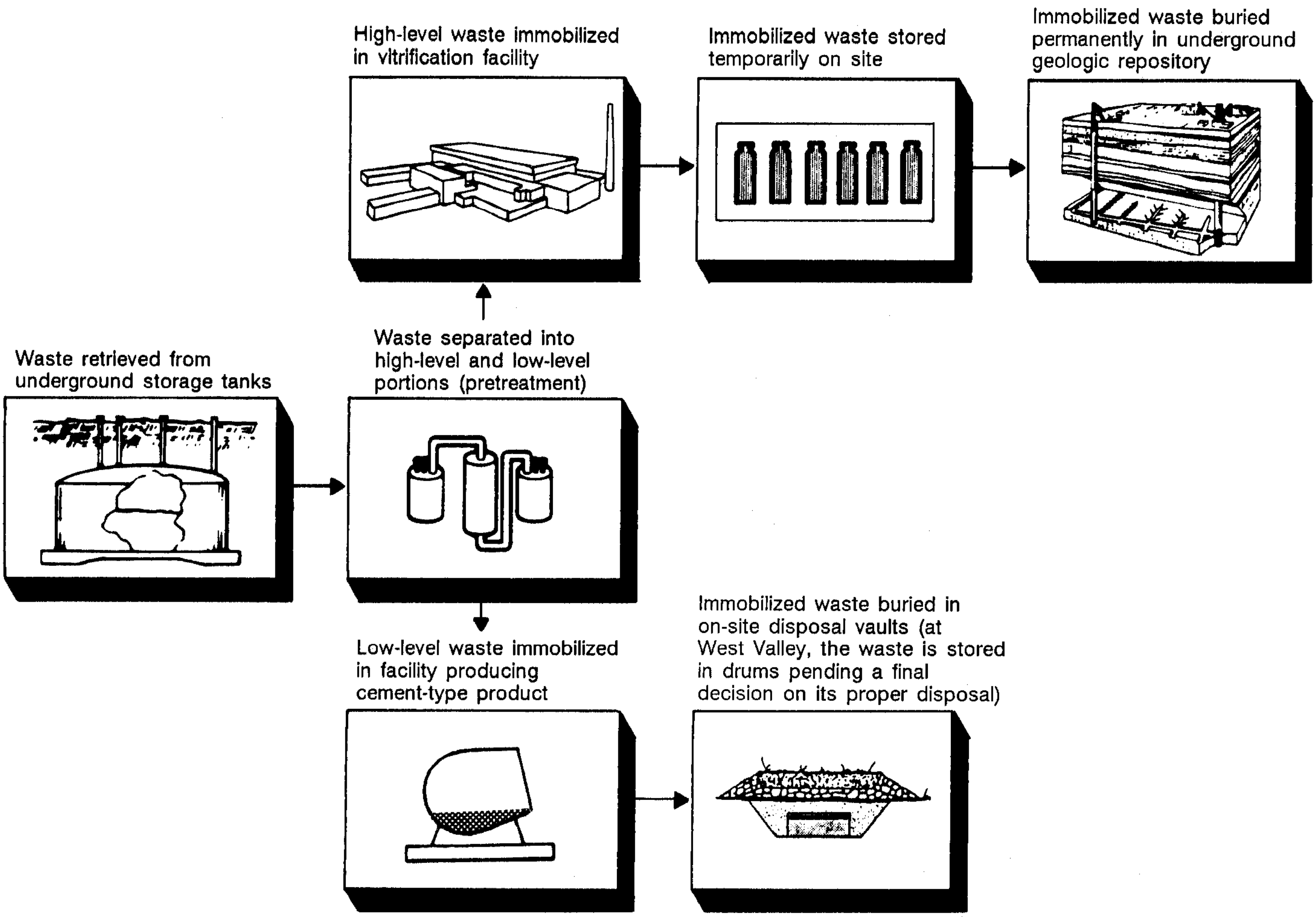
Vitrification Approach Selected for High-Level Waste at Three DOE Locations

High-level wastes will be vitrified at Savannah River, West Valley, and Hanford. Vitrification involves blending high-level waste with glass-forming materials to form a molten, radioactive product. The molten product is then poured into stainless steel canisters to cool and solidify. The glass-filled canisters will be stored at the sites for eventual transfer to the high-level waste repository.

DOE evaluated over a dozen different waste forms, such as calcine and concrete, before it selected borosilicate glass as the final waste form for storing its high-level waste from Savannah River, West Valley, and Hanford. According to DOE documents, borosilicate glass, which is similar to volcanic glass, was selected for a number of reasons including its (1) ability to withstand the waste's heat and radiation, (2) suitability for a wide variety of waste products, (3) suitability for large-scale production, and (4) compatibility with a full range of possible geologic structures at the repository.

Before the waste is vitrified, it will be removed from the underground storage tanks and separated into high-level and low-level portions in a step called pretreatment (see fig. 1.3). According to DOE officials, this step is desirable because it decreases the volume of high-level waste that must be vitrified and the low-level waste can be disposed of less expensively than high-level waste. At Savannah River and Hanford, DOE plans to convert the low-level waste into a cement-like product and dispose of it permanently in near-surface vaults on-site. At West Valley, this cement-like product is being placed in drums and stored on-site pending a decision on its permanent disposal location.

Figure 1.3: Basic Process for Treating High-Level Waste at Savannah River, West Valley, and Hanford

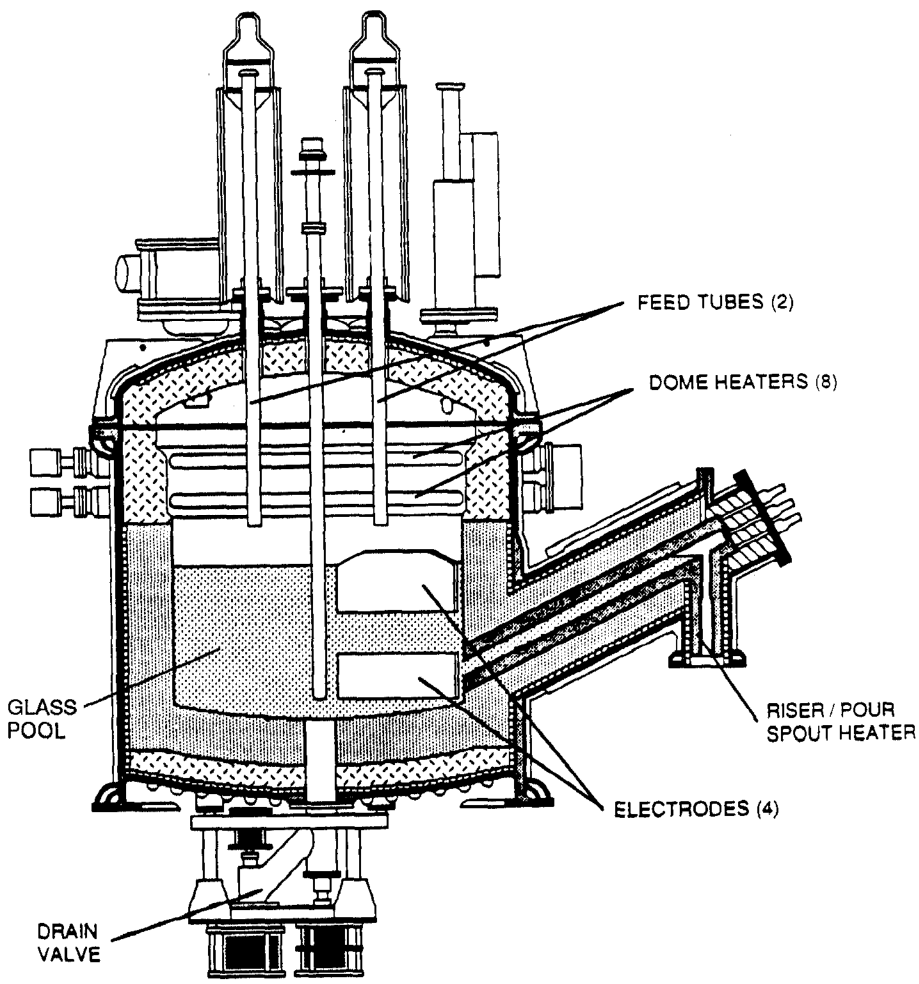


Source: Adapted by GAO from DOE illustrations.

The waste pretreatment methods will vary at each location because of differences in the spent fuels and reprocessing techniques. For example, the wastes at Savannah River, West Valley, and Hanford all contain various aluminum compounds. According to DOE, some aluminum strengthens the durability of the glass, but too much can cause glass-processing difficulties. The waste at Savannah River contains more aluminum than desired, so some of it must be removed. Therefore, Savannah River's process includes a step to remove excess aluminum.

After pretreatment, the high-level waste will be blended with glass-forming materials and fed into a melter to be vitrified. Figure 1.4 shows a schematic of a melter that will be used at Savannah River. The melter generates heat through an electrical current that passes between two pairs of electrodes. Additional heat is generated with heaters located above the glass pool. The waste and glass materials will be mixed for at least 40 hours. After mixing, the molten glass will be poured into stainless steel canisters about 10 feet tall and 2 feet in diameter. The canisters are then cleaned to remove external radioactive contaminates, welded shut, and stored on-site in an interim storage facility.

Figure 1.4: Melter Used in Vitrification Process



Source: Adapted by GAO from DOE illustrations.

High-Level Waste Immobilization
Technology Not Yet Selected for INEL

DOE has been evaluating different processing technologies for immobilizing the high-level waste at INEL. As of April 1989, DOE officials said that they are leaning toward a glass-ceramic waste form rather than vitrified borosilicate glass. (See sec. 5 for a further explanation of the process and DOE's rationale for favoring it.) DOE officials expect to make a final decision on the waste form in 1993.

DOE'S WASTE IMMOBILIZATION SCHEDULE

DOE estimates that the start-up dates for its high-level waste immobilization facilities at the four locations will range from 1992 to 2011. (Facility construction and operation schedules for each location are shown in table 1.) As shown in table 1, construction is under way at Savannah River and West Valley. The Hanford vitrification facility is in the design phase, and INEL is in an early planning stage of selecting the waste form and the processing technology.

According to DOE, the processing of high-level waste at the three defense sites--Savannah River, Hanford, and INEL--will be accomplished sequentially so that experience gained at one site can be applied to the others, thus achieving a more efficient use of resources. DOE documents indicate that Savannah River was selected as the first defense site to begin construction (1983) because its (1) wastes contain the highest amount of radioactivity[3] and (2) wet climate and higher groundwater table pose potentially greater risks to the environment there than at Hanford and INEL if leakage from the tanks should occur. Construction is scheduled to begin at Hanford in 1991 and at INEL in 2002. According to DOE, processing at INEL will begin last because the calcined waste is considered to be a relatively stable waste form, can be safely stored in the underground stainless steel bins for several hundred years, and is less likely to escape into the environment than the liquid wastes stored in tanks at the other sites.

DOE's construction schedule for West Valley, established in January 1989, reflects a considerable revision of earlier schedules. As discussed in section 3, difficulties experienced while trying to accelerate construction and funding limitations slowed the project completion and operational start-up of the vitrification facility about 8 years longer than was projected in 1984. At Savannah River, where construction is also under way, scheduled completion has slipped about 2 years to 1992 (see sec. 2).

According to DOE's schedule, it will take about 40 years before the backlog of accumulated high-level waste is immobilized. DOE expects that immobilizing the waste backlog will be completed in 1998 at West Valley (based on the January 1989 estimate), 2008

---

[3]As of Dec. 31, 1987, Hanford had more waste by volume, but Savannah River had about 56 percent of all radioactivity in DOE's inventory of high-level waste.

at Savannah River, 2008 at Hanford (double-shell tanks only),[4] and about 2028 at INEL. If defense production activities continue at Savannah River and INEL beyond these dates, further high-level waste processing at these sites will be required.

DOE WILL IMMOBILIZE HIGH-LEVEL WASTE BEFORE THE REPOSITORY IS READY

DOE is assessing the suitability of a site at Yucca Mountain, Nevada, for use as a nuclear waste geologic repository to permanently store high-level waste. According to DOE documentation, if the site is found to be acceptable, it will be ready to accept commercial high-level waste (such as spent fuel elements from nuclear-powered electricity generation plants) starting in 2003 and defense waste in 2008. Under DOE's immobilization schedule, however, all locations except INEL will have canisters filled with high-level waste stored on-site before the geologic repository is ready to receive them. DOE expects glass-filled canisters to be produced at Savannah River, West Valley, and Hanford in 1992, 1996, and 1999, respectively. DOE plans to store the canisters at all three sites until the repository is ready to receive them.

The high-level radioactive waste to be disposed of in the geologic repository must meet criteria established by the Nuclear Regulatory Commission (NRC). NRC's criteria set certain general standards, such as the requirements that the radioactive waste be in a solid form and that it be in a noncombustible form unless it can be demonstrated that it would not adversely affect the repository's safety and operation. To help ensure that these and other criteria are met, DOE has formed a Waste Acceptance Committee. According to the committee's charter, its objective is to "develop waste acceptance technical requirements and specifications and identify and resolve technical issues pertaining to the acceptance of high-level waste for disposal in a commercial geologic repository." The committee's membership includes, among others, representatives from the repository project and each of the four high-level waste sites that will produce the immobilized waste.

Once the repository's characteristics are known and it is judged to be suitable for the permanent storage of high-level waste, DOE will apply for an NRC operating license. DOE expects that the waste acceptance requirements will be refined as the repository program proceeds and will not become final until NRC licenses the repository. In the meantime, according to DOE officials, their planned approach is to produce the highest

[4]DOE plans to determine whether it will vitrify wastes held in Hanford's single-shell tanks and how long that process will take when an environmental impact statement is completed in 2002.

quality waste form possible to help ensure compliance with NRC standards.

ESTIMATED COST OF THE WASTE IMMOBILIZATION EFFORT

DOE estimates that it will cost about $13 billion (in fiscal year 1988 dollars) to retrieve, process, immobilize, and store the high-level waste until it can be moved to a permanent disposal site.[5] Of this estimated total cost, about $5.3 billion is expected to be spent at Savannah River, $0.9 billion at West Valley, $2.8 billion at Hanford, and $4.0 billion at INEL. Table 1.1 shows DOE's cost estimates to immobilize (1) the high-level waste accumulated at each DOE location when the processing starts and (2) those additional wastes generated at the site during the period from commencement of high-level waste immobilization to completion of the immobilization program. The latter estimate reflects anticipated operations and additional capital costs. As noted earlier, DOE expects that Savannah River and INEL production activities will generate high-level waste after the immobilization facilities start operating. How long these locations will continue production activities is unknown.

---

[5]For our presentation of the total cost of the immobilization program, we requested that DOE convert its "year-of-expenditure" cost estimates for the four projects to constant dollars. We did not request that DOE calculate the present value of this cost estimate, which would have taken into account that the costs for these projects will not occur until the future. Such a calculation would determine the amount of money that, if invested today at a selected interest rate, would be sufficient to meet expected future funding needs. For costs presented in sections 2 through 5, we elected to use the DOE cost estimates that were already prepared because they were readily available and sufficient to provide a general idea of costs for individual projects and various project components.

Table 1.1: Estimated Costs to Immobilize High-Level Waste
Fiscal year 1988 dollars in billions

Location	Immobilization costs for: Accumulated waste[a]	Immobilization costs for: Wastes generated after immobilization begins	Total
Savannah River	$3.64	$1.61[b]	$ 5.25
West Valley	.92[c]	0	0.92
Hanford	2.77	0	2.77
INEL	2.70	1.30[d]	4.00
			$12.94

[a]These estimated costs include research and development, waste characterization, immobilization facility design and construction, waste pretreatment processes and facilities, on-site canister storage facilities, and operational and other capital costs necessary to prepare and store the high-level waste pending shipment to the geologic repository. Hanford costs are limited to wastes stored in its double-shell tanks.

[b]This figure reflects estimated costs to process the high-level waste accumulated from start-up of the immobilization process (1992) until 2020. Immobilization activities are expected to continue indefinitely beyond this date.

[c]This estimate includes costs already incurred to decontaminate some existing facilities before they could be used for the project, and estimated costs to immobilize the low-level waste separated from the liquid high-level waste and immobilize the high-level waste.

[d]This figure reflects estimated costs to process the high-level waste accumulated from start-up of the immobilization process (2011) until 2037. Immobilization activities are expected to continue indefinitely beyond this date.

Source: DOE.

According to DOE, these estimates do not include costs such as the transportation of the canisters to the repository, the disposal fee charged by the repository, near-surface disposal of low-level wastes that result from pretreatment of the high-level waste, or facility decontamination and decommissioning. Additionally, at Hanford and INEL, some issues--which could greatly affect cost and schedule--will not be resolved for a number of years. These issues, discussed more fully in sections 4 and 5, include the amount of waste that will be treated at Hanford and the type of technology to be used at INEL. Resolution of these issues is not expected until early in the next century at Hanford and in 1993 at INEL. Thus, even if more refined estimates are prepared in the meantime, the cost of the program may be uncertain for some time to come.

SECTION 2

HIGH-LEVEL WASTE IMMOBILIZATION AT

THE SAVANNAH RIVER SITE, SOUTH CAROLINA

Established in the early 1950s, DOE's Savannah River Site encompasses about 300 square miles along the Savannah River near Aiken, South Carolina. The Savannah River complex has three nuclear materials production reactors,[1] two nuclear fuel processing facilities, and numerous support facilities. The Savannah River Site has been a major source of nuclear materials for defense programs and has provided nuclear materials for space, medical, and energy applications.

HIGH-LEVEL WASTE INVENTORY

Savannah River has 51 underground carbon steel waste storage tanks and, as of December 1988, approximately 34 million gallons of high-level radioactive waste. According to a DOE official, the waste is stored in 45 tanks--22 double-shell and 23 single-shell tanks. A DOE document indicates that future activities could generate about 2.5 million gallons of high-level waste annually.

Savannah River's high-level waste is in three forms: sludge, saltcake, and liquid:

-- Sludge, which is 11 percent of the waste by volume, contains about 61 percent of the total radioactivity. The sludge sits on the bottom of the tanks and consists of iron, manganese, aluminum, and other insoluble components. The principal radioactive elements are strontium and plutonium.

-- Saltcake is a solid that sits on a layer of sludge, represents about 39 percent of the waste by volume, and consists mainly of sodium salts. The primary radioactive element is cesium.

-- Liquid represents about 50 percent of the waste by volume. Like saltcake, the main component in the liquid is sodium salts and the primary radioactive element is cesium.

---

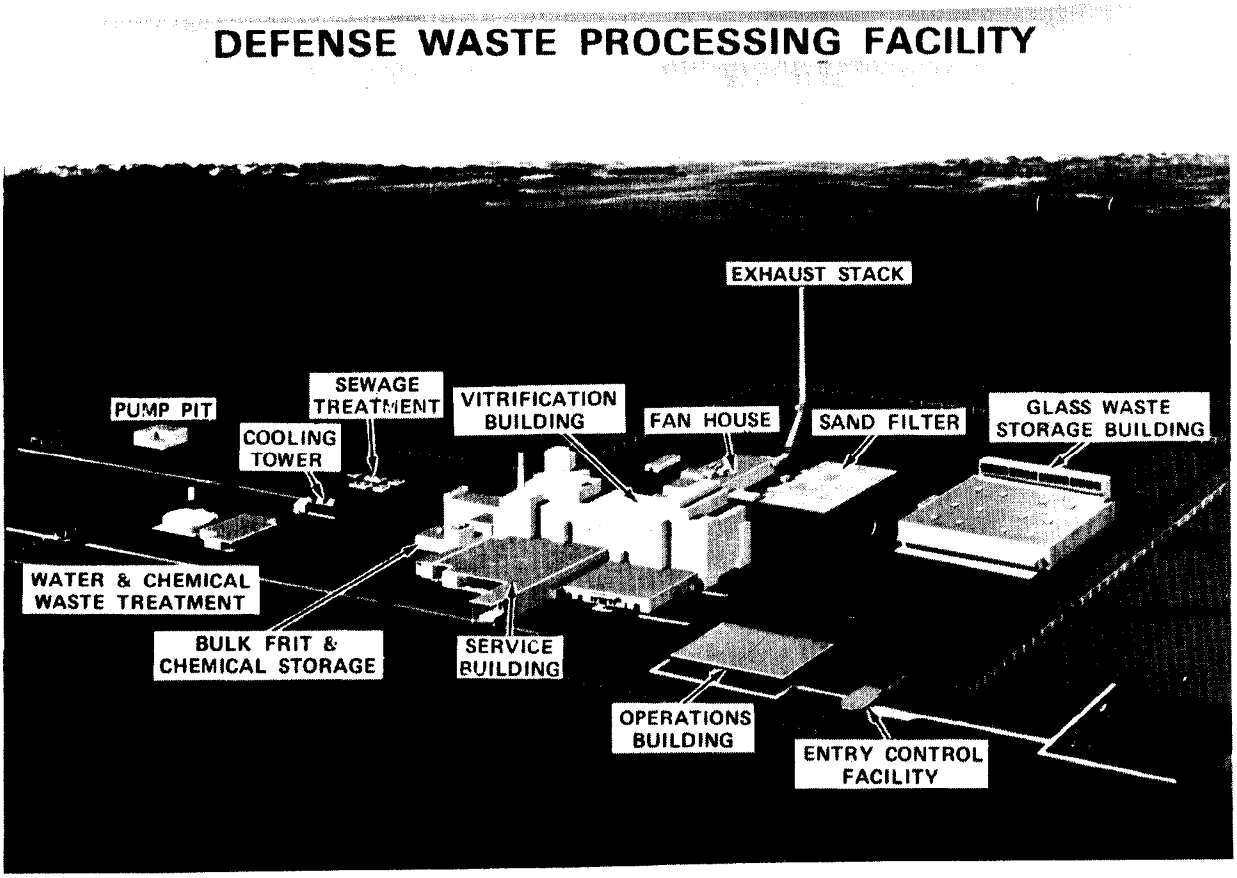
[1]As of September 1989, all three reactors were out of service because of safety concerns, and none are expected to restart production operations before late 1990.

HIGH-LEVEL WASTE IMMOBILIZATION PROCESS

Nuclear fuel reprocessing operations at Savannah River have produced four different waste types that will be pretreated and vitrified. The waste types result from different nuclear fuels or reprocessing techniques. In the waste treatment process, all four waste types will be blended and treated to separate the waste into low-level and high-level components. The low-level component will be processed into a cement-like product and placed in disposal vaults on-site. The high-level component will be vitrified into a borosilicate glass waste form and stored on-site to await ultimate disposal in a geologic repository.

As of September 1989, design of the Savannah River vitrification facility, called the Defense Waste Processing Facility (DWPF), was about 99-percent complete; and construction was about 96-percent complete, according to the project's chief of design and construction. The concrete vitrification building is 360-feet long, 117-feet wide, and almost 100-feet tall. (See fig. 2.1.) It is designed to resist tornado and seismic forces and provide shielding against the high levels of radioactivity. The building contains a system of barriers designed to separate the radioactive areas from the nonradioactive operating areas.

Figure 2.1: Defense Waste Processing Facility, Savannah River Site, South Carolina



Source: DOE illustration.

DWPF is designed to produce a maximum of 410 glass-filled canisters annually, each of them containing about 165 gallons of vitrified waste. The DWPF Deputy Project Manager estimates that once the facility is fully operational, about 16 years will be needed to process the backlog of accumulated wastes.

Supporting facilities for DWPF include a canister storage building designed to hold 5 years of glass waste production. A DOE document shows that another storage building will be constructed beginning in fiscal year 1993. This building is necessary because the storage building already constructed will be full by the end of 1996, and the federal waste repository is not scheduled to receive defense waste until 2008.

PROJECT SCHEDULE AND COST

Preliminary design of DWPF began in July 1979, construction began in October 1983, and vitrification is now scheduled to begin in January 1992. The scheduled start-up for the vitrification facility has slipped about 2 years from the date estimated when construction began in October 1983. According to DOE documents, the facility's start-up date was changed for the following reasons:

-- Delays in critical equipment delivery, unexpected project complexity, and limitations in the funds available in fiscal years 1986-88 caused a 9-month delay.

-- The time required to test simulated radioactive wastes and to demonstrate compliance with repository waste acceptance requirements extended the start-up another 16 months.

As of September 1989, the DWPF chief of design and construction estimated that the design, procurement, and construction of the high-level and low-level immobilization facilities was about $930 million (in year-of-expenditure dollars). When related categories of expenditures are added to this amount, the total increases to $1.25 billion.[2]

DOE documents indicate that the total estimated cost of the Savannah River vitrification project has increased about 1.5 percent since about the time construction began. According to DOE documents, the total estimated project cost has increased from $1.235 billion in March 1984 (made about 5 months after construction began) to $1.25 billion in April 1989. The estimated cost of the project has fluctuated since construction began in October 1983 for a number of reasons, such as changes in scope to include a low-level disposal facility, changes to meet enhanced fire protection requirements, and changes in procurement and construction costs. DOE estimates the annual operating costs to be about $115 million to retrieve, pretreat, and vitrify the high-level wastes at Savannah River.

The DWPF Deputy Project Manager told us he does not believe there are any technical difficulties that would significantly affect DWPF's current schedule and cost estimates. According to DOE and Savannah River contractor officials in November 1988, DWPF had identified a major technical problem when the system that removes organic materials from the waste during pretreatment was tested. The problem occurred after repeated test runs led to significantly increased waste-processing time. If left unresolved, according to a DOE official, this problem could cost millions of dollars to correct. In September 1989, however, the DWPF chief of design and construction told us that the system had been modified and the most recent tests indicated that the system should function properly. He considered it a minor concern, and it is being reported as such in progress reports to headquarters.

---

[2]These additional categories are plant engineering and design; design liaison, engineering studies, and operations testing; technical support; and related research and development.

SECTION 3

HIGH-LEVEL WASTE IMMOBILIZATION

AT THE WEST VALLEY SITE, NEW YORK

The West Valley Demonstration Project (Project) is located at the Western New York Nuclear Service Center (Center), West Valley, New York. The Center, owned by the state of New York, and operated between 1966 and 1972 by Nuclear Fuel Services, Incorporated (NFS) is the only commercial nuclear fuel reprocessing facility to have operated in the United States. In 1976, NFS ended its nuclear fuel processing activities. In 1980, DOE was directed by the West Valley Demonstration Project Act (P.L. 96-368) to, among other things, solidify the high-level waste stored at West Valley (about 572,000 gallons) and transport it to the geologic repository. In 1983, DOE began constructing the waste immobilization project and estimated that all waste would be solidified by 1990 for about $473 million. According to DOE's January 1989 estimate, the solidification completion date was extended about 7.5 years, and the cost estimate was increased to about $1.1 billion. However, according to a DOE official, the agency's recently released 5-year plan for environmental restoration and waste management could reduce the time and money required to complete solidification.

DOE RESPONSIBILITY FOR WEST VALLEY HIGH-LEVEL WASTE MANDATED BY THE CONGRESS

In 1972, NFS stopped fuel reprocessing operations to make modifications estimated to cost about $15 million and to take about 2 years to complete. A short time later, the U.S. Atomic Energy Commission (NRC's predecessor) imposed new and more stringent earthquake and safety criteria on the plant that, according to NFS, eventually raised the cost of modifications to an estimated $600 million. In September 1976, NFS announced its decision to terminate its nuclear fuel reprocessing activities, citing rising costs and uncertain regulatory requirements as key factors. No federal, state, or private entity accepted responsibility, either individually or cooperatively, for the nuclear wastes that remained at the site, and this situation led to federal legislation to resolve the problem.

On October 1, 1980, the President signed the legislation that directed the Secretary of Energy to carry out a high-level radioactive waste management demonstration project at the Center. The purpose was to demonstrate techniques in solidifying high-level radioactive wastes for final disposal. Among other things, the act directed the Secretary to

-- solidify, in a form suitable for transportation and disposal, the Center's high-level radioactive waste;

-- develop containers suitable for the waste's permanent disposal;

-- transport the solidified waste as soon as feasible to a federal geologic repository for permanent disposal;

-- dispose of the low-level radioactive waste and transuranic waste that are generated during the course of high-level waste solidification; and

-- decontaminate and decommission the tanks, facilities, and hardware that are used in connection with the project in accordance with NRC requirements.

Further, the act required the Secretary to enter into an agreement with New York State whereby the state would make available to DOE for the Project, without transfer of title, about 200 acres of the 3,345-acre Center. The act also requires the state to pay 10 percent of the Project's costs.

HIGH-LEVEL WASTE INVENTORY

During the facility's 6 years of operations, about 625 metric tons of spent nuclear fuel were reprocessed, generating about 572,000 gallons of high-level nuclear waste. This waste is stored in two single-shell tanks located in underground concrete vaults. One tank is made of carbon steel and the other is stainless steel.

-- The carbon steel tank contains about 98 percent (560,000 gallons) of the site's total waste. The waste in this tank was created during the reprocessing of spent uranium fuel. This waste, initially highly acidic, was converted into an alkaline solution to avoid corroding the tank. Over time, part of the radioactive waste has settled, forming a layer of sludge on the bottom of the tank. The sludge, which represents about 10 percent of the waste volume, contains heavy metals, sodium salts, and half of the radioactivity--mostly strontium. The liquid above the sludge contains sodium salts; its primary radioactive element is cesium.

-- The stainless steel tank contains about 12,000 gallons of waste that was generated from the processing of thorium-uranium enriched spent fuel. This waste is liquid and still acidic.

HIGH-LEVEL WASTE IMMOBILIZATION PROCESS

The Project's high-level waste is processed essentially as at Savannah River. (See fig. 1.3.) The liquid waste in the carbon steel tank is processed to separate high-level and low-level radioactive components. As of March 1989, about 25 percent of the liquid had been processed. After the liquid waste is treated, the sludge will be removed from the tank and also separated into high-level and low-level radioactive components. The high-level components from the sludge and liquid will then be mixed with the acidic waste from the stainless steel tank and pumped to the vitrification facility. The low-level portion of the waste is being solidified into a cement-like product and stored in drums on-site, pending completion of an environmental impact statement. After that time, a decision will be made to determine the permanent disposal site for the low-level waste.

DOE estimates that in vitrified form, the Project's high-level waste will fill about 300 stainless-steel canisters. The canisters will be stored on-site, pending shipment to the federal repository. According to a DOE Project official, DOE is studying the possibility of shipping the canisters to another federally owned facility for temporary storage as a means of accelerating closure of the Project's premises.

PROJECT SCHEDULE AND COSTS

DOE assumed operational control of the Project in February 1982. The Project premises include the chemical reprocessing facility, a spent-fuel receiving and storage area, high-level waste storage tanks, a low-level waste treatment facility, an NRC-licensed land disposal area, and some support facilities. DOE divided Project activities into two phases:

- -- Phase I activities include decontamination of existing facilities necessary to support the solidification effort, development of canisters to contain the waste for storage in the geologic repository, and solidification of the high-level radioactive waste.

- -- Phase II activities include transporting the glass canisters to the repository, decontaminating and decommissioning facilities used in the Project, and determining the proper disposal methods for low-level and other wastes generated by the Project and stored on site.

An important part of DOE's strategy for performing its waste disposal mission at West Valley was its attempt to accelerate the Project's construction during the design phase--an approach DOE refers to as "Actiontrak" (also called "fast-track"). According to DOE officials, the fast-track approach was an aggressive project management strategy that was intended to accelerate project completion and minimize costs. West Valley's major system acquisition plan, approved in February 1985, indicated that a 2-year schedule acceleration could result in a cost reduction of $20 million to $50 million. The fast-track strategy was abandoned in mid-1987 because of schedule delays and cost increases. As shown in table 3.1, DOE's estimate for Phase I costs have more than doubled since 1984, and the vitrification start-up date has been delayed at least 5 years.

Table 3.1: Chronology of Estimates Established for West Valley's Vitrification Operations and Phase I Costs
Dollars in millions

Date estimate established	Vitrification operations: Start[a]	Vitrification operations: Complete	Phase I cost[b]
March 1984	September 1988	March 1990	$ 436
March 1986	April 1989	October 1990	458
February 1987	November 1989	May 1991	488
April 1987	April 1991	October 1992	577
December 1987	October 1992	April 1994	800
January 1989	October 1996	September 1998	1,106
August 1989	October 1993	March 1995	890

[a]Start of high-level radioactive materials processing.

[b]Year of expenditure dollars.

Source: DOE.

As shown in table 3.1, DOE estimated in January 1989 that vitrification would begin in October 1996 and be completed (including all of Phase I) in September 1998. This is about 17 years after the Project started. (Phase II is scheduled to be completed in about fiscal year 2020.) According to a DOE official in August 1989, if money is provided according to the schedule and amounts described in DOE's recently released 5-year plan, vitrification could be completed about 3 years sooner.

The most significant change in schedule and cost estimates occurred between early 1987 and 1989. As indicated in table 3.1, in January 1989, DOE expected Phase I to take more than 7 years longer to complete at a cost of about $618 million more than estimated in early 1987. DOE Project officials attributed the delay and associated cost increases primarily to (1) unsuccessful fast-track efforts and (2) funding shortfalls.

Schedule Delays

DOE officials told us that, under the fast-track strategy, construction was initiated on certain activities before design work was sufficiently completed. This was done in part because DOE officials believed that the technology for waste solidification was sufficiently developed and could be applied at West Valley without extensive feasibility and design work. However, the fast-track approach did not work. Lack of sufficient design work resulted in inaccurate cost estimates, numerous design changes during construction, and delays in other Project activities. For example, according to the Project Director, when it was discovered that design-related problems led to a $12-million cost overrun for the low-level waste-processing system, funds were shifted from vitrification facility activities in order to complete the low-level system. The Project Director told us that DOE lacked sufficient funds to do both systems and gave priority to the low-level system because it enabled the Project to begin reducing the liquid in the high-level waste tanks. This shift in funds delayed vitrification design work, thus delaying the Project schedule by 1 year.

According to the Project Director, after it was recognized that the low-level waste system would cost an additional $12 million, DOE instituted several project management changes, including abandoning the fast-track philosophy in favor of the more conventional design-before-construction approach. The Director also said a comprehensive reevaluation of Phase I costs was performed, which led to the $800-million estimate in late 1987.

Funding shortfalls also resulted in schedule delays, according to DOE officials. They cited shortfalls in fiscal years 1986-88 as contributing to the extensions and said that, in fiscal year 1988 for example, funding was reduced by about $10 million, resulting in a 1-year delay in vitrification construction work.

Cost Increases

In January 1989, DOE estimated that Phase I could cost about $1.106 billion (year-of-expenditure dollars). DOE estimated its cost share to be $995 million, with New York State providing the remaining $111 million in funds, services, and credits for the value of the facilities provided the Project. In addition, DOE estimated that it would cost $372 million to $514 million (1988 dollars) to complete Phase II.

Table 3.2 shows DOE's explanation for the $618-million increase in Phase I estimated costs between February 1987 and January 1989. According to DOE Project officials, about $418 million (or 68 percent) of this increase is the result of two factors: continued operating costs incurred during the 7.5-year delay--for such things as maintaining technical staff on-site, environmental monitoring, security, and other activities required by DOE regulations ($259 million)--and price escalations that occurred during the delay for these and other items ($159 million).

Table 3.2: West Valley Phase I Cost Growth Between February 1987 and January 1989
Dollars in millions

Element of cost growth	Amount
Project operating costs incurred during the 7.5-year schedule extension	$259
Escalation (price increase) incurred during the 7.5-year schedule extension	159
Underestimate of vitrification system costs ($60 million) and increased costs due to funding limitations ($23 million)	83
Contingency fund increase	54
New work (e.g., environmental compliance, physical security upgrades)	51
Underestimate of low-level waste-processing system construction	12
Total	$618

Source: DOE.

Future funding limitations were cited as causing the bulk of the Phase I cost revision from December 1987 to January 1989--from $800 million to $1.1 billion. The Project Director, according to his statements to us in January 1989, thought Phase I could be completed for about $800 million if funds were available as originally projected in December 1987. However, according to DOE officials, DOE's fiscal year 1990 congressional budget request reflected lower funding levels for fiscal years 1990-92 than projected in the $800-million estimate. The Project Director said these reductions, while lowering costs in these particular years, would add to the overall expense of the program because of price increases (inflation) and additional operating costs incurred during the longer construction period.[1]

According to the Project Director in June 1989, if funds were provided sooner than anticipated in the fiscal year 1990 congressional budget request, total Phase I costs could be less than the $1.1-billion estimate. According to a DOE official in August 1989, if money is provided according to the schedule and

[1]Although delays due to funding limitations may increase both year-of-expenditure and constant-dollar costs, the present value may fall because the costs will occur further in the future.

amounts described in DOE's recently released 5-year plan, Phase I could be completed for about $216 million less than the January 1989 estimate. (This year-of-expenditure estimate is equivalent to $110 million in fiscal year 1988 dollars.)

According to DOE officials, funding delays are likely to be the only major factor affecting cost and schedule in the future. Except for potential funding delays, they do not foresee factors that would significantly increase Phase I costs or further delay the schedule.

SECTION 4

HIGH-LEVEL WASTE IMMOBILIZATION AT THE HANFORD SITE, WASHINGTON STATE

The Hanford Site, which occupies 560-square miles in southeastern Washington State, was established in 1943 to produce plutonium for nuclear weapons. In February 1988, DOE announced that because of reductions in the estimated need for plutonium, production of plutonium at Hanford's N Reactor would cease. However, several other Hanford facilities will operate until the mid-1990s to process defense materials. Hanford also continues to conduct various other activities, such as research on advanced reactors, the environment and energy, and the management of radioactive waste.

HIGH-LEVEL WASTE INVENTORY

As of December 1988, Hanford stored about 57 million gallons of nuclear waste in 149 single-shell and 28 double-shell carbon steel tanks. The single-shell tanks contain about 37 million gallons; the double-shell tanks contain about 20 million gallons.

DOE's current plans to immobilize high-level and other tank waste include only the waste in double-shell tanks. The waste in these tanks is in four forms: sludge, saltcake, slurry, and liquid.

-- Sludge, which is about 9 percent of the waste by volume, contains most of the radioactive elements except cesium. The sludge, which settles out when the waste is changed from acid to alkaline, consists of various chemicals and such radionuclides as strontium and plutonium.

-- Saltcake, which forms when liquid waste is concentrated through an evaporation process, is about 4 percent of the waste by volume. Saltcake consists mainly of sodium and aluminum salts, and a major radionuclide is cesium.

-- Slurry, which is a concentrated liquid waste with suspended solids, is about 10 percent of the waste.

-- Liquid is about 77 percent of the waste by volume. Like saltcake, the main component in the liquid is sodium compounds, and a major radionuclide is cesium.

In addition to the tank wastes, Hanford plans to dispose of 597 strontium and 1,341 cesium high-level waste capsules produced before 1985. Hanford's high-level waste was processed to remove most of the strontium and cesium in order to save tank space.

Further separation and encapsulation of the cesium and strontium is not planned. DOE distributed over 1,000 of these capsules to commercial and other users and expects that nearly 800 of them will be returned for eventual disposal. According to DOE documents, the capsules will be packaged and shipped to the geologic repository without being vitrified.

HIGH-LEVEL WASTE IMMOBILIZATION PROCESS

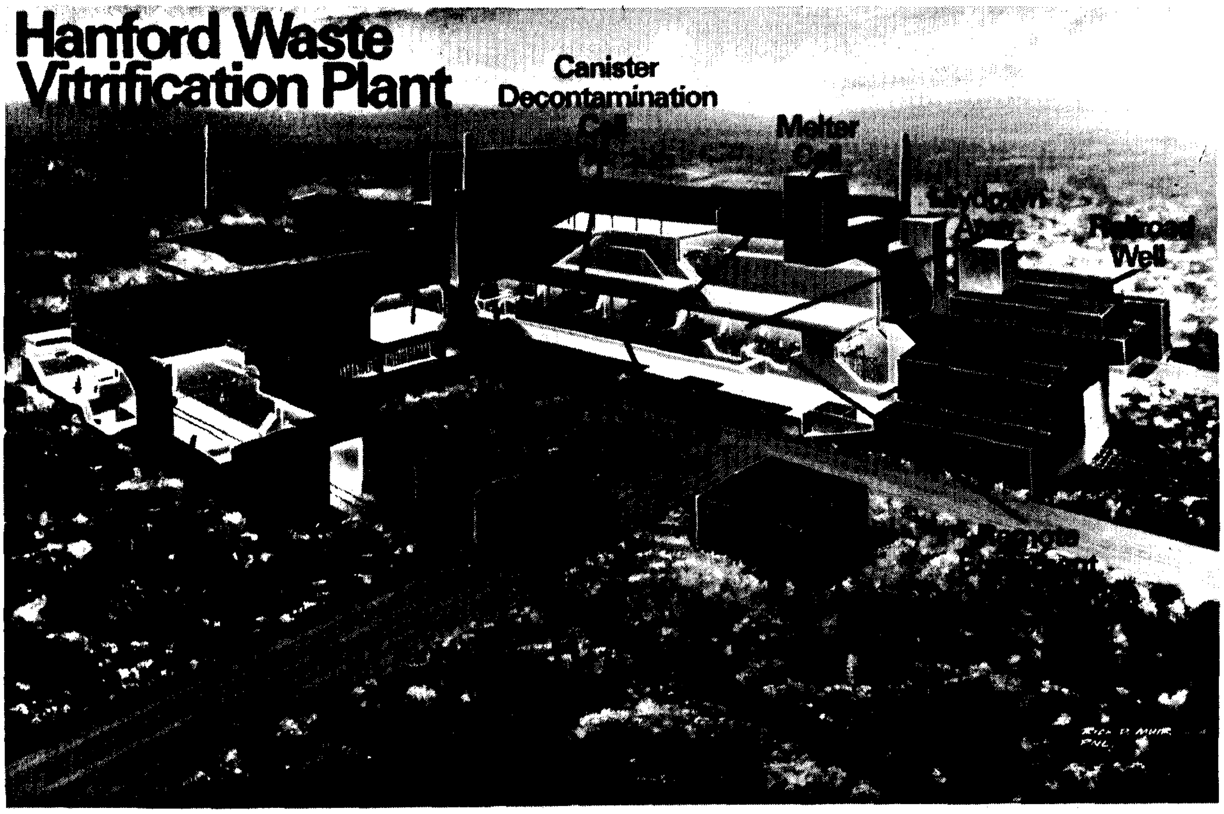
High-level waste from Hanford's double-shell tanks will be treated essentially in the manner outlined in section 1. Of the approximately 20 million gallons of waste in the double-shell tanks, however, only about 7 million gallons require pretreatment. According to a DOE contractor official, the remaining 13 million gallons is low-level waste that will be immobilized in a cement-like product for on-site disposal.

The 7 million gallons of double-shell tank waste that will be pretreated contain four different waste types resulting from different nuclear fuels or reprocessing techniques. Unlike their approach at Savannah River, where the separate waste types are blended together, DOE officials say that the Hanford waste has some unique characteristics that may warrant separate treatment activities for each waste type. DOE is currently developing the pretreatment process for all four waste types.

DOE plans to use existing facilities, including B Plant (a 44-year old facility that was most recently used for recovering radioactive products from stored waste) to pretreat all four waste types. B Plant is currently being upgraded to pretreat the first waste type; and when this waste has been processed, DOE plans to shut down B Plant and refit it before pretreating any of the remaining three waste types.

Hanford's high-level waste will be vitrified at a facility called the Hanford Waste Vitrification Plant (HWVP). (See fig. 4.1.) Its design is based on the design of the vitrification facility at Savannah River and modified to accommodate the unique features of Hanford's wastes and the technology needed to treat them. The vitrification building will be a reinforced concrete structure designed and constructed to meet DOE criteria for tornado and seismic resistance, radiation protection, and other requirements.

Figure 4.1: Hanford Waste Vitrification Plant, Hanford, Washington



Source: DOE illustration.

According to the HWVP Deputy Director, HWVP plans to produce about 320 glass-filled canisters annually. At this rate, about 6 to 9 years will be required to vitrify the waste backlog. HWVP support facilities include a glass canister storage building that will store the double-shell tank canister production. The storage facility design will allow the storage capacity to be increased if necessary.

PROJECT SCHEDULE AND COST

About 35 percent of HWVP's preliminary design phase (the second of three design stages) was completed in March 1989. During this phase, the plant's configuration was refined, and the preliminary design plan will serve as the baseline for detailed design. HWVP construction is scheduled to begin in July 1991, and radioactive waste is scheduled to be processed beginning in December 1999.

As of March 1989, DOE's estimate for the construction of HWVP is $965 million (in year-of-expenditure dollars). When related categories of expenditures are added to this amount, the total rises to about $1.435 billion.[1] According to a DOE official, this estimate does not include the cost of low-level waste treatment facilities or the cost of modifying B Plant for pretreatment processing.

According to DOE, funding delays can result in increased estimates of the project's cost. For example, in January 1989, DOE increased its estimated cost for constructing HWVP from $920 million to $965 million because of possible funding reductions in fiscal years 1990-91.[2]

Two other factors, in addition to the availability of funds, may affect the operating schedule and overall cost for HWVP. These factors, which have yet to be resolved, are the uncertainty about the total volume of waste to be treated and the successful development of a process for treating three of the four waste types.

Volume of Wastes to Be Vitrified

The uncertainty associated with the volume of waste requiring vitrification at Hanford centers on the single-shell tank wastes. DOE plans to "characterize" the single-shell tank wastes--that is, study the waste to determine what types of waste, and how much of each type, the single-shell tanks contain. When this process is completed, DOE should know how much of the waste needs to be vitrified. According to DOE, the decisions will be made in 2002 when a Record of Decision will be issued based on a supplemental Environmental Impact Statement on the single-shell tank waste.

If DOE decides to retrieve and process large volumes of single-shell tank wastes for disposal, the ability to treat these wastes in B Plant is a major uncertainty. Because the characteristics of waste in the single-shell tanks are unknown, according to DOE officials, they do not know what type of facility or treatment may be needed. Thus, B Plant may or may not be suitable for treating the wastes. In addition, B Plant's age--

---

[1]These additional categories include research and development, environmental and safety design analysis, capital equipment not related to construction, and technical support.

[2]Although funding delays may increase both year-of-expenditure and constant-dollar costs, the present value may fall because the costs will occur further in the future.

already about 44 years old--may be a factor. A DOE contractor document indicates that, if the waste from all 149 single-shell tanks is treated, it could require that B Plant operations be extended an additional 20 to 24 years.

Pretreatment Process for Remaining Three Waste Types

To treat three of its four double-shell tank waste types, DOE is planning to use a new pretreatment process that will reduce the amount of vitrified waste. According to DOE, experiments to test this process have been performed; and while experiments performed to date indicate that the process will work well, additional testing is required. If further testing shows that the process is not effective, the alternative pretreatment process, according to DOE, would result in an increased volume of vitrified glass. This in turn could increase the amount of time and the cost for vitrifying the waste, and increase costs and disposal requirements at the geologic repository. However, DOE officials believe that the risk associated with this uncertainty is sufficiently low to allow them to proceed with project planning and execution at this time.

SECTION 5

HIGH-LEVEL WASTE IMMOBILIZATION AT THE IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO

The Idaho National Engineering Laboratory (INEL) was established in 1949 as a nuclear reactor testing site. Located on 890 square miles of desert in southeastern Idaho, INEL activities include nuclear fuels reprocessing, nuclear safety research and waste management, and development of advanced energy concepts.

A major source of high-level nuclear waste at INEL is the Idaho Chemical Processing Plant (ICPP), which reprocesses spent nuclear fuel, primarily from naval nuclear propulsion reactors and reactor-testing programs. A small amount of high-level waste is produced from reprocessing fuel from nondefense research reactors.

HIGH-LEVEL WASTE INVENTORY

In 1963, ICPP began solidifying the liquid high-level waste into a dry granular material through a process called calcination. The calcined product remains an acidic, high-level radioactive waste but requires only about one-eighth the storage space of the original liquid. In addition to saving space, the solid calcine is considered a more stable waste form than liquid.

Initially, the liquid waste is stored in large underground stainless steel tanks contained in concrete vaults until sufficient quantities are available for calcining. The dry calcine is stored in underground stainless steel bins contained in concrete vaults. These bins are designed to last at least 500 years. According to DOE, seven sets of bins have been constructed and four of the seven were filled as of July 1989. Additional bins will be constructed as required.

According to DOE, as of December 1988, INEL had about 2.9 million gallons of high-level waste stored on site. This volume includes about 900,000 gallons of calcined waste and about 2 million gallons of liquid waste awaiting calcination.[1]

---

[1]According to DOE, the 900,000 gallons of calcine is equivalent to about 6.3 million gallons of liquid waste. (DOE often presents the volume of calcined waste in cubic meters. For the sake of comparison with other types of waste in this fact sheet, we have converted this measurement into gallons.)

HIGH-LEVEL WASTE
IMMOBILIZATION PROCESS

A DOE official told us that since the ICPP waste was converted to calcine rather than an alkaline form as it was at Savannah River, Hanford, and West Valley, it does not require the pretreatment steps described in section 1.[2] However, according to a DOE official, the calcined waste is not in a form that is suitable for permanent disposal in the geologic repository because it could possibly disperse as airborne particles or dissolve easily if it comes in contact with water.

DOE is examining processes in addition to vitrification to immobilize the calcined waste for ultimate disposal. According to a DOE document, vitrifying INEL's current and future calcined wastes would produce a volume of immobilized waste greater than that at Savannah River and Hanford combined. Therefore, a major focus for waste form and technology selection at INEL is to minimize the volume of the final product.

The preferred waste form for the calcined waste, according to a DOE official, is a glass-ceramic product. DOE expects that, when compared to vitrification, the glass-ceramic product will require less glass additive and this, in turn, means the volume of waste and number of canisters can be minimized. DOE estimates that a glass-ceramic-filled canister can accommodate about 2.5 times the volume of waste as that of a similar-sized glass-filled canister.

According to a 1987 DOE contractor cost study, the cost savings associated with the glass-ceramic process could be substantially lower than if the waste were vitrified--primarily because fewer canisters will need to be transported to, and disposed of, in the geologic repository. DOE estimates that INEL could produce about 8,800 glass-ceramic canisters in the first 10 years of its solidification project. Vitrifying the same volume of waste could require 23,000 canisters. At DOE's 1987 estimated cost of about $350,000 to transport and place each canister in the repository, vitrifying the waste could cost about $5 billion more than the glass-ceramic product for just the first 10 years of production.

DOE documents indicate that tests show that the durability of the glass-ceramic waste form is similar to that of the borosilicate glass to be produced in the planned vitrification

---

[2]According to a DOE contractor document, the calcined waste could be redissolved and separated into high- and low-level waste components, but preliminary cost estimates indicate this step would be one of the most expensive alternatives and result in large quantities of low-level waste being disposed of on-site.

plants. DOE officials told us they plan to decide on the INEL waste form and technology in 1993.

PROJECT SCHEDULE AND COST

The ICPP waste immobilization facility is currently in the early planning phase. According to an April 1989 INEL briefing document, INEL had begun testing the process necessary to produce an acceptable glass-ceramic waste form. DOE officials expect design and construction of the facility to begin in 2002 and waste processing to begin in 2011. They estimate that if the glass-ceramic waste form and technology are selected, immobilizing the backlog of calcined high-level waste will be completed in about 2028. According to a DOE official, DOE expects that the facility could still reprocess nuclear fuel beyond 2028 and thus will continue the waste-processing operations.

Estimated construction costs of the facility are from $600 million to $800 million. A DOE official told us that DOE plans to construct a small-scale version of the immobilization facility in the mid-1990s.

MAJOR CONTRIBUTORS TO THIS FACT SHEET

RESOURCES, COMMUNITY, AND ECONOMIC DEVELOPMENT DIVISION, WASHINGTON, D.C.

Carl J. Bannerman, Assistant Director
Ronald M. Owens, Assignment Manager

SEATTLE REGIONAL OFFICE

Leonard L. Dowd, Regional Management Representative
Christopher S. Herndobler, Evaluator-in-Charge
Nancy R. Purvine, Evaluator
Stanley G. Stenersen, Senior Reports Analyst

(301833)

Requests for copies of GAO reports should be sent to:

U.S. General Accounting Office
Post Office Box 6015
Gaithersburg, Maryland 20877

Telephone 202-275-6241

The first five copies of each report are free. Additional copies are $2.00 each.

There is a 25% discount on orders for 100 or more copies mailed to a single address.

Orders must be prepaid by cash or by check or money order made out to the Superintendent of Documents.

United States
General Accounting Office
Washington, D.C. 20548

Official Business
Penalty for Private Use $300

First-Class Mail
Postage & Fees Paid
GAO
Permit No. G100