Appendix C

Costs of Environmental Restoration at the Department of Energy Nuclear Weapons Complex

INTRODUCTION

Much attention has been devoted to budgetary matters of late, with the Department of Energy (DOE) environmental restoration budget being no exception. The prospect of a long-term environmental cleanup at the Nuclear Weapons Complex, given the experience of Superfund cost inflation, raises serious concerns about funding requirements. Because of DOE's lengthy budgetary process, costs must be projected years into the future. With weapons production and engineering construction projects, cost estimators are usually dealing with known technologies and well-defiied specifications. With environmental remediation, however, technologies and specifications are much less well-defined. The art of environmental cost estimating is just now leaving its infancy.

Initial estimates have been made by DOE for its environmental restoration program, but the validity of these estimates has been widely debated. The uncertainty regarding environmental cost estimates may necessitate some divergence from the traditional defense budget allocation process. At the same time, some efforts are needed to reduce the uncertainty.

This appendix examines DOE's environmental restoration cost estimates in an attempt to get a clearer picture of the uncertainties involved. The aim of this analysis is to determine the mechanisms by which DOE estimates environmental restoration costs, to examine the divergence between those estimates and actual costs incurred, and to assess the implications of those findings for policymakers.

The process of environmental restoration is in the very early stages of a long-term (at least 30-year) process. Cost estimates for such a project are bound to have a large margin of error. Nevertheless, important decisions are based on them. The experience on which existing DOE estimates are based is very limited. Most environmental restoration (ER) projects are only at the stage of site characterization, a process that can vary considerably from site to site. Some remediation work, however, has been undertaken at DOE facilities. To shed some light both on DOE's estimation track record and on the potential for current estimates to vary, these remediation projects were examined in detail.

REMEDIATION PROJECTS FOR WHICH COSTS HAVE BEEN ANALYZED

The Office of Technology Assessment (OTA) identified a list of remediation projects at Nuclear Weapons Complex facilities for which estimated and actual cost data would be requested. Because of the limited number of remediation projects that have been completed in the recent past, the list was short. In drawing up the list, projects were chosen according to the following criteria:

1. Work on the project was completed or underway as of FY 1990.
2. The work planned represented typical remediation activity, in terms of the work breakdown elements, that may be expected to occur in remedial action at any industrial site.
3. The work, for the most part, was carried out under the environmental restoration *portion* of the Five-Year Plan, in most cases excluding decontamination and decommissioning (D&D) projects (in several instances, D&D and corrective action projects were included because they were very similar to ER-type projects and because few ER projects had been completed or initiated).
4. The list was confined to remedial activities as described above, to the exclusion of remedial investigation/feasibility study (RI/FS) work.

The list of projects was drawn primarily from information in the 1989 Five-Year Plan and the attendant activity data sheets (ADSs) and supplemented by discussions with DOE. Remedial activities completed or underway were identified at nine facilities: The Feed Materials Production Center (Femald), the Hanford Reservation, the Idaho National Engineering Laboratory (lNEL), the Kansas City Plant, the Lawrence Livermore National Laboratory (LLNL), the Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant, the Pinellas Plant, and the Savannah River Site. OTA was unable to obtain any information indicating that other remedial activities had been completed in the recent past. For projects that have not been completed, actual cost data were requested for the portion of the project completed as of the end of 1989.

Projects at those sites for which cost data were requested are as follows:

Fernald

- Groundwater monitoring well installation
- pumping of contaminated groundwater

Hanford Reservation

- A-29 Ditch interim remediation (interim activity deemed irrelevant to study; no cost estimate available on final closure)
- B-Pond interim stabilization (interim activity deemed irrelevant to study; no cost estimate available on final closure)
- 183-H solar basins decontamination and decommissioning
- Groundwater monitoring well installation (only some costs provided)

Idaho National Engineering Laboratory

- Idaho Chemical Processing Plant (ICPP) gravel pit and tank farm cleanup (data not available)
- SPERT IV waste removal and remedial action (only some data received)
- Capping of CPP injection well
- Groundwater monitoring well installation (only some data received)

Kansas City Plant

- *Rernov~* of **Polychkxinated** biphenyl (PCB) contaminated soils and capping at outfall 002

Lawrence Livermore National Laboratory

- Groundwater remediation at LLNL (received data on proposed groundwater remediation)
- Groundwater monitoring well installation

Oak Ridge National Laboratory

- SWSA 6 dynamic compaction and grouting demonstration projects
- SWSA 6 interim capping
- Groundwater monitoring well installation

Oak Ridge Y-12 Plant

- *S-3* Pond closure
- Oil land farm closure
- Groundwater monitoring well installation

Pinellas Plant

- Groundwater remediation at 4.5-acre site

Savannah River Site

- Closure of M-Area settling basin/Lost Lake
- AIM Area groundwater remediation
- Mixed waste management facility closure
- Groundwater monitoring well installation

Letters requesting specific information, including estimated costs and actual costs incurred, were sent to all appropriate field offices on the dates noted above. The purpose of requesting this information was to identify variations in unit costs among facilities, to determine the ability of contractors to estimate actual costs, to evaluate the potential for incurring unexpected costs for specific remediations, and to determine the ability of DOE/contractors to retrieve detailed cost and site characterization information.

The cost information that has been supplied, in many cases, is rounded, aggregated, or disaggregate from information available to field engineers. As such, it may not represent *exact* **costs** for the activities shown. However, after lengthy conversations with field engineers at all of the responding facilities, OTA believes that considerable effort was made to provide data that is as accurate as possible. *Great caution should be taken in using these data for any purpose other than that intended in this report. The* manner in which many of the environmental restoration activities described in this report are accounted for makes extraction of specific unit costs difficult. OTA believes that although field engineers made every effort to portray unit costs accurately, further use of the data by other researchers should be preceded by direct communication with field personnel to avoid misunderstanding.

COST DATA PROVIDED BY FIELD OPERATIONS

Fewer than one-half of the data originally requested was provided. In most cases, both estimated costs and actual costs were not available. DOE does not routinely collect detailed cost information on its remedial actions but rather entrusts this responsibility to its contractors and subcontractors. At the majority of sites, OTA research efforts became productive only when contact was made with contractor personnel. Following is a summary of the information provided. All relevant field offices were given the opportunity to review this report in draft form.

Albuquerque Operations Office

The Albuquerque Operations Office (AL) maintains administrative responsibility for two of the projects listed-the 002 outfall at Kansas City and the 4.5-acre site at Pinellas. AL's initial attempt to estimate costs of environmental restoration at its field oillce in a comprehensive manner was begun in 1987, although some facilities prepared separate cost estimates (including Roe@ Flats, no longer reporting to AL, and Kansas City). This effort was undertaken by Roy F. Weston under contract to AL. Given the remediation needs of each facility, Weston estimated aggregated costs for each field office. These costs were never verified by AL but were apparently based on EPA unit cost assumptions.

After implementation of the Environmental Restoration (ER) Program in FY 1988, a detailed list of environmental problems was created for each field office for the ER program implementation plan, which identified expected remediation needs at the task level. To facilitate the estimation of costs for these tasks, AL again contracted with Weston to prepare a cost estimation document that could be used by the field offices. This document was completed in November 1988.

The cost estimation guidelines were divided into two sections. The costs for RI/FSs were based on the perceived complexity of the task-a one-stage characterization effort for simple tasks and a two-stage effort for more complex tasks. For remedial action costs, generic remedial actions were created for five cases, and work breakdown schedules were outlined for each. Unit costs were then developed and adjusted for location. These unit costs provided the basis for estimating the cost of each task at the field offices. Unfortunately, the assumptions used at the field offices for defining the tasks were not recorded; only the results (i.e., total costs) were put into the implementation plan. Because of time constraints, AL performed only a limited review and revision of these cost estimates prior to including them in the first Five-Year Plan issued by DOE in the fall of 1989. All of the costs estimated in this way were assigned a low level of confidence. AL identified, in the 1989 Five-Year Plan, a total ER fimding need of $1,439.8 million for FY 1989 through FY 1995. This includes assessment, cleanup, D&D, and research and development (R&D) at all priority levels.

In December 1989, AL requested backup information on assumptions made by the field offices in preparing the implementation plan to allow for a higher leveI of confidence in the estimates. The revised costs are being entered into a time-line computer program to allow schedule and cost tracking as each task proceeds. AL plans to request that all field offices for which it has responsibility use this or a similar format to provide detailed reports on ER tasks. This system should allow for more consistent and comprehensive reporting on ER activities among all of AL's field offices.

Pinellas Plant (see table C-1)

The total ER funding identified for the Pinellas Plant for the FY 1989-95 period was reported as $23.117 million in the 1989 Five-Year Plan. The corresponding amount identified for the 4.5-acre site remediation was reported as $4.5 million (an additional $750,000 was spent on the site prior to FY 1989) in the ADS. The level of confidence of this estimate was reported as high in the ADS, based on definitive design.

Table C-l-Costs Reported for Pinellas Plant

Monitoring well costs

Monitoring wells were installed as part of the site characterization phase. Over the period 1986-89,38 wells were drilled to depths averaging 20 feet. Total cost of monitoring well installation was $115,000, or about $150/foot.

***Soil excavation and removal* (1986 doliars)**

Gost of soii excavation
Actual: $20,000 ($66/ton) (This was estimated as the applicable portion of an $80,000 contract for characterization and an emergency removal.)

Cost of soil transportation (using a completely enclosed containerized vehicle)
Actual: $25,000 ($0.165/ton-mile)

Cost of soil disposal
Actual: $33,400 ($110/ton)

***Groundwater extraction and treatment* (1989 dollars)**

Cost of recovery well installation
Actual: $40,000 ($228/foot for seven wells averaging 25-foot depth)

Cost of well sampling
Estimated: $20,000/year ($192 per sample) (Samples will be taken once a week, both before and after the water enters the air stripper.)

Cost of well operation and maintenance
Estimated: $15,000/year (includes operation and maintenance on the air stripper)

Treatment facility construction cost
Estimated: $50,000 (based on 30-gallon/minute treatment capacity, operating 24 hours/day, with 4 to 6 hours maintenance per month; this equals about 15 million gallons/year; $3,333 per million gallons of annual capacity)

Water discharge costs
Estimated: $2.25 per thousand gallons (costs of discharge to POTW)

Cost of decommissioning
Estimated: $35,000 (Treatment will take an estimated 2 to 3 years.)

SOURCE: Office of Technology Assessment, 1990.

The 4.5-acre site is located on private property adjacent to Pinellas Plant property. The site was used as a disposal area for drums containing solvents. The site was first investigated in 1985, and a Feasibility Study was completed in November 1987. The drums and the contaminated soil were removed to an EPA-approved landfill in 1985. That soil was never analyzed to determine contaminant levels. Low levels of contamination remain in an estimated 35 million gallons of groundwater, which is less than 20 feet below the surface (1).

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DOE has agreed to clean up the groundwater under the guidance of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); however, no consent orders have been issued, and the site is not considered a Superfund site. The Florida Department of Environmental Regulation (FDER) is the relevant regulatory authority.

The surficial aquifer is about 25 feet thick, approximately 1 to 4 feet below the surface, and separated from the Floridan Aquifer by the Hawthorn formation. The saturated zone consists of fine sand, silt, and clay. The closest populated area is 0.5 mile north of the site. The initial Interim Remedial Action Plan (approved by FDER) consisted of pumping the groundwater from seven extraction wells to a holding tank. The water was discharged to a publicly owned treatment works (POTW). This activity was carried out from December 1988 to January 1989. At that time, a high concentration of methylene chloride was encountered, causing a temporary halt to the interim action. A new treatment system is now being designed that will include air stripping.

A total of 303 tons of contaminated soil was removed from the site in 1986 and disposed at an Environmental Protection Agency (EPA) approved landfill 500 miles away in Pinewood, SC. To treat the contaminated groundwater, seven extraction wells were drilled, each with 4-inch diameter, to a depth of 25 feet. Cleanup goals have not yet been established because the primary aim of this interim action is to draw the contaminant plume back onsite from adjacent property. Engineering cost estimates for the 4.5-acre site were made by CH2M Hill and reviewed by GEND Engineering, as well as by DOE personnel. CH2M Hill is the prime contractor for engineering design; as of January 1990, construction had not been started on the air stripper.

According to AL personnel, experience so far on this and similar projects indicates that because of a lack of staff expertise, DOE was not able to assess the validity of contractor costs. To solve this problem, AL has hired a contractor whose sole responsibility is to review feasibility studies and costs for ER projects.

Kansas City Plant (see table C-2)

The total ER funding identified in the 1989 Five-Year Plan for the Kansas City Plant amounted to $36.0 million for FY 1989-95. The total cost of the 002 outfall remediation was reported at $637,458 (incurred in FY 1988 and FY 1989 in the ADS). The remediation cost (excluding concrete flume construction, engineering, site work, and removal of contaminated liquids) was reported at $385,169 or $255/ton of contaminated soil. The costs reported are actual, and the level of confidence is therefore high. Estimated costs were not provided by DOE and were calculated by OTA with assistance from DOE field staff.

Table C-2-Costs Reported for Kansas City Plant
(1988 dollars)

Cost of excavation	
Estimated:	$7,266 ($8.40/ton based on removal of an estimated 865 tons; $14.53/cubic yard based on estimated 500 cubic yards)
Actual:	$12,674 ($8.40/ton based on removal of 1,509 tons; $10.56/cubic yard based on 1,200 cubic yards)
Cost of transportation (a long-bed, open-top, soft-cover truck was used to transport the soil 795 miles to Emelle, AL)	
Estimated:	$83,500 (estimated by OTA based on reported combined transport and disposal cost of $183,000; cost per ton-mile is not calculated because the density of the estimated 500 cubic yards of soil was unknown at the time, although it was believed to be less than actual)
Actual:	$115,875 ($0.09/ton-mile based on transport of 1,633 tons)
Cost of disposal	
Estimated:	$99,500 (estimated by OTA based on $184 per cubic yard of disposal cost for estimated 541 cubic yards of soil and kiln dust, includes proportionally the same amount of kiln dust as actually added; plant engineers indicated that the disposal cost was known at the time of estimate)
Actual:	$238,480 ($146/ton; $184/cubic yard)
Combined transport and disposal cost	
Estimated:	$338/cubic yard
Actual:	$274/cubic yard
Other costs (includes backfill and topsoil “cover” and fly ash)	
Estimated:	$15,417 (based on estimated use of 650 tons of clay and 88 tons of topsoil)
Actual:	$18,140 (based on use of 750 tons of clay and 83 tons of topsoil)
Total cost of remediation	
Estimated:	$205,683
Actual:	$385.169

SOURCE: Office of Technology Assessment, 1990.

The 002 outfall contaminated area comprised less than 1 acre containing 1,200 cubic yards of soil (about 200 cubic yards was sediment of higher contamination) contaminated with PCBs, with concentrations as high as 792 parts per million (ppm)[1]. Approximately 1,509 tons (based on a soil density of 1.26 tons per cubic yard) of contaminated soil were excavated from the outfall to a level of 1 ppm, combined with 124 tons of kiln dust, and disposed offsite in Emelle, AL. Clean clay soil (750 tons) was used to refill the area, and a concrete flume was constructed from the storm sewer discharge point to the Indian Creek. A layer of topsoil (83 tons of material) was placed over the surrounding area. Work was completed under the Toxic Substances Control Act (TSCA), prior to signing a Consent Agreement. EPA Region VII had regulatory control of the cleanup. The remediation was

@, sample was 792 ppm; others ranged from 5 to 16 ppm.

required to comply with a National Pollution Discharge Elimination System (NPDES) permit. Soil removed amounted to 1,509 tons; it has been estimated that only 865 tons would have to be removed.[2] The difference between the estimated and the actual cost of remediation is in part due to this underestimation in the quantity of contaminated soil. Estimated unit costs were inflated to some extent to account for some expected increase. Initial quantities were estimated by IT Corp. and reviewed by Allied-Signal. IT Corp. was Allied Signal's subcontractor for the remedial design. Construction was subcontracted to ENSCO Environmental Services.

The total cost of the remedial action was 87 percent higher than estimated, partly because the amount of contaminated soil was 140 percent higher than estimated. As mentioned above, the estimated cost was inflated to account for an expected increase in the amount of soil that would need to be excavated. Discussions with project engineers indicate that the underestimation in soil amounts was due to technical difficulties in characterizing the site. The decision was made to save money on detailed characterization and to proceed with remediation. Details of the contamination were well known, but to determine the extent would have entailed bringing a drilling rig to the site. Because of the configuration of the land, this would have been extremely expensive; a road would have been required to bring the rig into the are% and even then, only one side of the outfall could have been sampled because of the levee grade. A permit would also have been required to build the road Note that a road was eventually constructed for remediation, but not in the time frame allowed for investigation. It was not believed that further characterization would change the choice of remedy, so remedial action was begun. Site engineers doubt that determining the extent of contamination prior to cleanup would have reduced remediation costs significantly.

Richland Opertions Office (RL)

The Richland Operations Office has responsibility for operating the Hanford Reservation. Data for Hanford's 1989 Five-Year Plan were taken from existing plans and budgets as of April 1989. Responsibility for gathering cost information was given to the Westinghouse Hanford Company Environmental Division; the submittals were reviewed by DOE RL senior officials. Some preliminary cost estimation work was performed in 1987 by Science Applications International Corp. (SAIC) under contract to Westinghouse. According to SAIC, "the purpose of this work was to develop a strategy for the characterization and remediation of potential CERCLA and RCRA Resource Conservation and Recovery Act] section 3(X)4(U) inactive sites in sufficient detail to enable the development of costs and schedules" (2). Costs were addressed therein based on the type of unit to be remediated, not on the specific characteristics of each individual site (i.e., "generic Hanford units" were developed for which remediation costs were estimated for a variety of technologies). It is not known how strictly the 1989 Five-Year Plan cost estimates adhere to the SAIC cost estimates.[3] An examination of SAIC data indicate that comparison would be difficult.

According to RL's predecisional draft, a field office financial review board was formed to confirm the validity of the final cost estimates for inclusion in the 1989 Five-Year Plan. Each ADS was reviewed and assigned a level of confidence.[4] According to RL's Five-Year Plan, "The budget estimates tend to reflect a 'success oriented' approach to activity data sheet workscope completion, even though recent experience indicates the evolution of more stringent and costly regulatory requirements" (3). This statement is apparently an expression of the belief held by some Hanford personnel that, under the recently complekxi Federal Facilities Agreement with EPA and the State of Washington, Hanford will face increasingly stringent standards as new technologies are developed They attribute this in part to the inexperience of technical staff at the State level, which results in regulation "by the book" rather than by reasoned engineering judgment.[5]

The total ER budget identified in the 1989 Five-Year Plan for RL amounted to $1,127.4 million over the period FY 1989-95. This includes assessment, cleanup, D&D, and hazardous waste technology. No red remedial activities have been completed to date at Hanford. The A-29 Ditch and B-Pond interim remediation consists only of installing a bypass line for liquid effluent to B-Pond The ditch and unused areas of the pond will be covered with clean fill until an RI/FS can be completed. These activities are considered closures of treatment, storage, and disposal units and come under the regulatory authority of the Washington State Department of Ecology. Remedial action for these units is not expected until 1996 and beyond. These two activities were not considered relevant to this cost analysis, and further data were not requested.

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[2] By volume, the amount of contaminated soil was initially estimated at 500 cubic yards; the actual amount was 1,259 cubic yards. In addition, the soil was found to contain more rock than expected. This difference in soil density was not accounted for in the excavation unit cost estimate. Records were not kept for soil volume (cubic yards). However, a typical soil density for Kansas City (excluding rock) i100 pounds per cubic foot.

[3] The site numbers in the SAIC report do not correspond to the facility/waste area grouping numbers in the activity data sheets.

[4] The methods of estimation and levels of confidence were defined in the predecisional draft. No particular method of cost estimation was recommended.

[5] Paul Day, EPA Region X, indicated that the regional office is attempting to address this problem of ever-increasing costs by offering cooperation and technical assistance to the State and DOE.

183-H Solar Basins Decontamination and Decommissioning (see table C-3)

The 183-H solar basins were used for the treatment of cooling water from H Reactor and for the storage and evaporation of liquid chemical waste. A leak detected in one of the basins in 1977 resulted in groundwater contamination. The primary contaminants are chromium, nitrate, uranium, sodium, and technetium. The decontamination and decommissioning of the four basins consist of removing the liquids and solidified sludge and demolishing the enclosing structures. After this, the surrounding area will be sampled, and a cap will be installed. The total estimated cost of D&D on the basins, to be completed in FY 1992, of $21.4 million is based on conceptual engineering estimates and work done to date. The estimate has a medium level of confidence.

The basins comprise an area of 0.6 acre (26,332 square feet) and, as of early 1990, had an estimated 35,860 cubic feet of sludge containing solvents, heavy metals, and radioactive materials remains in place. A total of 7.8 million liters of contaminated water has been removed through evaporation or solidification from the basins, and an estimated 193 million liters of groundwater is believed to be contaminated. The basins are being closed as a RCRA treatment, storage, and disposal unit under the direction of the Washington State Department of Ecology.

The D&D activities consist of the following:

1. All liquids have been evaporated, transformed into a crystallized solid material, or solidified and removed from the basins.
2. Sludge was removed and packaged in 55-gallon drums, which are now stored in the 200 West Area Central Waste Complex, Retrievable Waste Storage Area.
3. Concrete surfaces within the basin were wet sand-blasted, and spent grit was packaged in the same manner as sludge.
4. Concrete will be sampled and tested to determine residual contaminants.
5. The basins will be demolished by using standard practices, and the rubble will be disposed of according to the level of contamination. (The rubble is expected to have been adequately cleaned so that it can be classified as nonregulated waste.)
6. Soil below the concrete floors of the basins will be sampled to determine if any hot spots exist in the surrounding area.
7. A cap will be installed, and postclosure care and monfioring will be carried out for a minimum of 30 years.

Costs for the 183-H basin D&D were obtained only for the sludge removal, packaging, and storage phases (steps 1 through 3). This activity occurred from 1985 through early 1990. Included in reported costs are the removal of 61,583 cubic feet of solidified sludge, its packaging in 55-gallon drums and transport to the storage facility, groundwater monitoring over the 1985-90 period, and the costs of storage. All of the work was estimated and completed by Westinghouse and monitored through its D&D program office. Further detail on the actual costs and estimated costs were not available because cost accounting has not been done on a unit cost basis.

Table C-3-Cost Reported for Hanford 183-H Solar Basins (1989 dollars)

Cost of soraping, grit blasting, and packaging (includes transportation of paokaged waste 10 miles to on-site facility) Actual: $4,754,000 ($77.20/cubic foot)
Cost of storage (of 8,211 55-gallon drums) Actual: $1,813,000 ($29.44/cubic foot on average)
Cost of groundwater monitoring program (inoludes installation of some monitoring wells) Actual: $2,863,000
Total cost of sludge removal and storage, 1985-90 Actual: $9,430,000 ($153/cubic foot)
Cost of monitoring well installation at Hanford Actual: $125,000 per well ($417/foot)
Annual cost of sampling analysis Actual: $11,500 per well
Annual cost of well operation and maintenance (for 400 wells) Actual: $1.1 million ($2,750 per well)

SOURCE: Office of Technology Assessment, 1990.

Costs for the full 183-H solar basin D&D project are not yet available because work is expected to continue until 1992, preliminary estimates on waste volumes have changed as a result of rain and evaporation, and the costs of retrievable waste storage change annually. Preliminary cost estimates are therefore considered unreliable for projecting actual final costs.

Savannah River Operations Office (SR)

Attention to environmental problems at Savannah River began relatively early. The characterization of waste at SR started in 1981, with refinements in 1983. By 1984, the seven chemicals, metals, and pesticides (CMP) pits, covering approximately 2 acres, were closed at a cost of about $2.1 million. Closure consisted of excavation, capping, interim storage of excavated waste, installation of a leach field, and installation of monitoring wells. This closure was undertaken with no regulatory impetus, with verbal approval from the South Carolina Department of Health and Environmental Control (SCDHEC). Groundwater remediation began in the A/M Area at about the same time. As a result of this early work, SR and its current prime contractor, Westinghouse Savannah River Co., feel confident about their environmental restoration program plans and the associated cost estimates.

Prior to the formulation of the 1989 Five-Year Plan, remediation activities at SR were guided mainly by RCRA. However, development of an interagency agreement has shown that it would be prudent to ensure that remediation work will comply with both RCRA and CERCLA. EPA has been working with SR to integrate RCRA and CERCLA procedures, but this has been difficult. Despite this difficulty, SR personnel feel that the ER process has been running relatively smoothly.

At Savannah River, ER project details are identified by Westinghouse's Waste Management and Environmental Project Division staff.[6] Initial cost estimates for these projects are typically made by a full service design subcontractor, and then reviewed by Westinghouse. The final estimate is sent to Westinghouse's project management team and to SR. Most of SR's ER projects have not been "line item" activities and, therefore, have not had to be submitted for review to DOE headquarters. Such a review has been requested occasionally, when SR suspected that an estimate was controversial. The U.S. Army Corps of Engineers has also been asked to review some estimates.

Once remedial activity has begun, cost accounting is carried out by Westinghouse. Subcontractors submit a monthly cost report to Westinghouse, which then adds this to the total operations project cost. Westinghouse reports the monthly cost to SR. Apparently, the costs for ER activities are rolled into other project costs, so it is difficult to determine, at the monthly reporting level, what is actually being spent on remedial activities. When SR was asked for the costs of remedial actions, staff indicated that these were not readily available and would have to be provided by Westinghouse.

For the preparation of the 1989 Five-Year Plan, SR called on Westinghouse Savannah River Co.'s (WSRC) Environmental Restoration and Groundwater Protection Section, which monitors and assists all WSRC operating units with ER activities and interfaces with SR.[7] This group is responsible for the ER program, RCRA, RCRA facility investigations (RFIs), Federal facility agreements (FFAs), CERCLA, groundwater remediation, waste site closures, water use, and RCRA quarterly reports. The same group, under Du Pont's prime contractorship, also developed a generic program plan for conducting RFIs and site-specific plans.[8]

Cost estimates for the 1989 Five-Year Plan were made by assuming particular technologies at each site and using historical costs incurred in employing those technologies elsewhere at Savannah River. Characterization and assessment costs were based on EPA data on the costs of RI/FSs. The Westinghouse cost estimating group was not involved in making these estimates, and the people making the estimates were not cost estimators. To test the validity of the initial cost estimates, environmental coordinators in operating units were consulted and an informal complexwide survey was undertaken to collect comparable cost information. It was determined that the estimated costs for SR were within a reasonable range.

The ER cost estimates that appeared in the 1989 Five-Year Plan were often assigned a high level of confidence, based on SR's proven track record in remediation work and historical cost information. The validity of these estimates depends on the accuracy of the choice of technology for each site. The funding identified for SR for the period FY 1989-95 amounted to $466.1 million in the 1989 Five-Year Plan.

M-Area Settling Basin/Lost Lake Closure (see table C-4)

The M-Area settling basin received electroplating waste from M-Area operations, and the Lost Lake area acted as an overflow for the basin. The water and the sludge in the basin were contaminated with heavy metals and depleted uranium.

The basin and related seep area covered approximately 2 acres, and the adjacent Lost Lake is approximately 35 acres. The volume of contaminated soil (in and around the Lost Lake area) amounted to about 59,000 cubic yards, and the volume of contaminated sludge found in the basin amounted to about 5,000 cubic yards. Approximately 6 million gallons of contaminated water was present in the basin. During remedial action, heavy rainfall resulted in an additional 7 million gallons of water being deposited in Lost Lake, which had to be removed as part of the closure process.

The M-Area basin is being remediated under RCRA, with EPA and SCDHEC having regulatory authority. The RCRA closure plan was undertaken by Du Pont and Black & Veatch and was approved in July 1987. The physical closure, undertaken by OHM Corp., was about 98 percent complete as of February 1990 (completion had been scheduled for the end of FY 1989).

Closure of the area consisted first of dewatering the basin, treating the water, and discharging it to a surface stream under an NPDES discharge permit. The remaining sludge in the basin was treated via plate and frame filter

[6] These people are generally project engineers, not cost estimators. Westinghouse cost estimators have not been involved in estimating ER projects to date.

[7] Each operating unit also has an environmental coordinator, who reports to Westinghouse through the Manufacturing Division head.

[8] The RFI program plan, prepared by Du Pont for the Environmental Division, Savannah River Operations Office, U.S. DOE (revised November 1988).

Table C-4-Costs Reported for Savannah River M-Area Basin (In 1986 dollars)

Cost of basin water treatment (includes dewatering)		
	Estimated:	$320,760 (8 cents/gallon for estimated 4 million gallons)
	Actual:	$444,379 (6.6 cents/gallon for actual 6.747 million gallons)
Cost of soil excavation from Lost Lake and disposal in M-Area basin		
	Estimated:	$350,000 ($7.78/cubic yard for estimated 45,000 cubic yards)
	Actual:	$500,000 ($8.47/cubic yard for actual 59,000 cubic yards)
Cost of sludge treatment (inotudes dredging)		
	Estimated:	$502,408 ($1.00/gallon for 500,000 gallons estimated)
	Actual:	$1,893,342 ($1 .00/gallon for 1.9 million gallons actual)
Cost of dewatering Lost Lake		
	Estimated:	$83,804 (6 oents/gallon for estimated 1 million gallons)
	Actual:	$300,572 (4.3 centdgallon for actual 6.954 million gallons)
Cost of backfilling		
	Estimated:	$68,000 (estimated amount of dean fill not available)
	Actual:	$85,000 ($8.50/cubic yard for 10,000 cubic yards of dean fill)
Cost of cap installation (includes materials, see description above)		
	Estimated:	$450,000 (estimated area unknown)
	Actual:	$600,000 ($6.00/square foot)
Cost of cap operation and maintenance (annual)		
	Estimated:	$10,000 (10 cents/square foot)

SOURCE: Office of Technology Assessment, 1990.

press, dredge, pugmill, cement silo, and conveyors. This treatment stabilized contaminants in the sludge, which was then returned to the basin. The Lost Lake area, which had filled with rainwater, was dewatered and the soil was excavated to background levels of contaminants. This contaminated soil was backfilled in the basin. About 10,000 cubic yards of clean fill material were used to backfill excavated areas and complete the closure. The basin bottom was not lined before the soil and stabilized sludge were redeposited.[9] The area was capped with local kaolin clay, a Hypalon cover, and topsoil, and a runoff control system was installed to meet RCRA requirements. The total cost of the project, 80 percent of which was attributed to the basin closure, is now estimated at $5.8 million (the total estimated cost in November 1989 was $5.3 million); $3.7 million was allocated for FY 1989 in the 1989 Five-Year Plan. A high level of confidence was associated with this estimate because the project was ongoing.

The total expected cost for the M-Area/Lost Lake closure is now $5.8 million; the project was originally authorized for $3 million. The main factors responsible for this 93 percent increase in costs are the higher than expected amount of sludge to be processed, the greater than average amount of rain that fell during the remedial action, and the unexpected requirement for a wastewater treatment facility. Unit costs appear to have been relatively well-estimated. Estimates were based on subcontractor bids provided in 1985-1986; the subcontractor was generally held to original unit prices, except for the factors mentioned above.

A/M Area Groundwater Remediation (see table C-5)

The A/M Area Groundwater Monitoring Program encompasses the A/M Area including the Savannah River Laboratory (SRL), an area comprising about 5,371 acres. The largest plume, in M Area, covers approximately 1,239 acres; SRL contamination covers an area of about 183 acres. The groundwater and soil under A/M Area are contaminated with trichloroethylene (TCE) and tetrachloroethylene (PCE) (concentration levels range from less than 1 to 100,000 parts per billion (ppb)), which were used as degreasing agents in the M-Area fuel fabrication facility. The performance of this project is described in appendix B.

Also under this task is the remediation of groundwater contamination in the northern sector of A/M Area under the SRL. Another investigation is underway in the southern sector of the A/M Area. A prototype air stripper from the Reactor Materials Department will be used for the northern sector remediation. Finally, this task includes a vadose zone program, which is a pilot program to remove residual contamination from the vadose zone by using horizontal wells. Cost estimates for these two pilot projects are not available, but characterization costs alone for the vadose zone project are estimated at $250,000. The total amount of funding identified in the 1989 Five-Year Plan for the A/M Area groundwater remediation project was $8.8 million for FY 1989-95.

Facility engineers indicate that the small increase in actual v. estimated cost was the result of several design changes required of the subcontractor during the construction period.

Mixed Waste Management Facility Closure (see table C-6)

The Mixed Waste Management Facility (MWMF) constitutes a 58-acre portion of a 200-acre radioactive waste burial ground (the remainder of the area will become a CERCLA site). The 200-acre area served as a burial ground and storage area for contaminated equipment, empty drums, tritium crucibles, reactor scrap, and containerized waste. The 58-acre site contains a wide

[9] The bottom liner was not required because the basin was considered a RCRA interim status facility.

Table C-5-Costs Reported for A/M Area Groundwater Remediation

M-Area monitoring well installation (1989 dollars)
  Estimated: deep wells (295-300 feet) $132/foot (includes stainless steel casing)
  Shallow wells (130-270 feet): $103/foot
  Oversight costs: $500/day per rig
  Mobilization costs: $100 per rig (contractor A); $500 per rig (contractor B)

Well sampling costs
  Estimated: $200,000/year for 235 monitoring wells
  Annual sampling for 12 point of compliance wells: $2,600 per well
  Quarterly sampling for 12 point of compliance wells: $400 per well (three quarters only)
  Quarterly sampling for other monitoring wells: $160 per well

Cost of well operation and maintenance
  Estimated: $15 to $30 annually per well
  Actual: extremely variable

Groundwater treatment system
  Cost of recovery well installation (1985 dollars)
  Estimated: $350,000 ($1.59/foot for 11 wells averaging 200-foot depth)
  Actual: $350,000

Cost of sampling (1989 dollars)
  Estimated: $2,000 for two samples (influent and effluent sampled quarterly)

Cost of well and air stripper operation and maintenance (includes costs of disposal of treated water to NPDES outfall)
  Estimated: $110,000 ($550 per million gallons)
  Actual: unknown (This is treated as an overhead cost and is hidden in the total overhead cost of the raw materials operating budget.)

Treatment facility construction costs (200-million gallon per year air stripper)(1985 dollars)
  Estimated: $4.45 million ($22,250 per million gallons of annual capacity)
  Actual: $4.515 million (22,575 per million gallons of annual capacity)

SOURCE: Office of Technology Assessment, 1990.

variety of waste types, including boxes containing mixed debris, random mixed debris, containers of absorbed waste oil, containers of scintillation solution, waste lead, cadmium, and silver, as well as heavy equipment. The estimated volume of contaminated soil in the 58-acre area is 3.75 million cubic yards.

Groundwater at the site is at average depths of 30 to 40 feet below the surface; however, perched water conditions due to intermittent clay lenses exist 15 to 20 feet below the surface in some areas.

The MWMF will be closed by dynamic compaction and capping as a RCRA closure under SCDHEC. In dynamic compaction, a 20-ton weight is dropped by a crane onto old trenches identified by ground-penetrating radar. The compaction reduces settling of contaminated material and helps maintain cap integrity. The area will be covered with a 3-foot-thick kaolin clay cap and an additional 2 feet of soil and will be monitored. The total

Table C-6-Costs Reported for Savannah River Mixed Waste Management Facility (1989 dollars)

Cost of site preparation
  Actual: $4,189,850 ($72,239/acre; includes clearing, stripping,borrow site grading, and MWMF grading)
Cost of equipment mobilization
  Actual: $750,000
Additional construction costs
  Actual: $500,000 (to present)
Dynamic compaction operation and maintenance cost
  Actual: $2,990,000 ($51,551/acre)
Cost of cap installation
  Actual: $7,670,000 ($332,241/acre; $7.63/square foot)
Monitoring costs
  Unknown

NOTE: All costs are actual; estimated costs for the lump sum subcontract were not broken down into the increments above.)

SOURCE: Office of Technology Assessment, 1990.

baseline cost of design, procurement, and remediation was estimated at $52.8 million, with $37 million accounted for by an expected “lump sum” subcontractor bid for the dynamic compaction and capping procedure. The original estimate to close the site had been much higher ($118 million) because the contractor’s estimate included a higher level of worker protection than ultimately deemed necessary (4). Once the lump-sum contract was let, the total cost was revised further downward to $35.029 million (the lump-sum subcontract was reduced to $24.44 million, including a 6 percent contingency). It now appears that the final actual cost of the dynamic compaction and capping will be less than $18 million-lower than expected due to a fewer number of drops required per acre than originally estimated.

Remedial design for the site, as well as cost estimation and cost review, was conducted by C.T. Main and reviewed by DOE SR; construction is being performed by Nello L. Teer. Testing on the project began in October 1987, and full-scale dynamic compaction began in February 1989. Closure is almost complete. The total funding allocated to the closure in the 1989 Five-Year Plan amounts to $42.7 million for FY 1989-91. The level of confidence associated with this estimate was high because SR is well into closure activities.

Oak Ridge Operations Office (OR)

The Oak Ridge Operations Office oversees the activities of the Y-12 Plant, ORNL, the former gaseous diffusion plant at K-25, and the Feed Materials Production Center at Femald, OH. Cost estimates for the environmental restoration and waste management activities for the 1989 Five-Year Plan were made by Martin Marietta field engineers. For activities at the conceptual design stage, estimates were based on that design and reviewed by DOE headquarters in its annual validation review. For activities with no conceptual design, estimates were based on the expected level of effort and best engineering judgment. These estimates were made without the use of any consistent methodology and underwent no formal review process prior to inclusion in the Five-Year Plan. OR staff were included in the decisionmaking process for these estimates, however. Estimated funding requirements for OR's ER program were reported at $3.397 million for FY 1989-95.

Environmental restoration cost estimates are being coordinated by OR for the 1990 Five-Year Plan. Both DOE and Martin Marietta have created a centralized ER division to conduct this effort.

Y-12 Plant (see table C-7)

Eight RCRA closures are among the remedial activities being carried out under the ER program at Y-12. The total cost of these closures, which cover a combined area of about 92 acres, has been estimated at $46.8 million. At least four of the closures were completed as of the end of 1989. The total estimated ER budget for Y-12 in the 1989 Five-Year Plan was $340 million for 1989-1995. Data were requested on two of the closures, the S-3 Ponds and the Oil Land Farm.

S-3 Ponds—The S-3 Ponds are four ponds covering an area of approximately 5.1 acres. The ponds were used from 1951 to 1984 as a disposal area for a variety of aqueous wastes, containing uranyl nitrate, nitric acid, and aluminum nitrate. Each pond contained about 2.5 million gallons of contaminated water, and the four combined contained a total of 26,900 cubic yards of contaminated soil and 26,900 cubic yards of contaminated sludge.

Contaminant ts included nitrates in a concentration as high as 10,620 ppm and, in general, exceeded 1,000 milligrams per liter in groundwater. Mercury contamination in excess of 0.002 milligram per liter was also found in the area of the ponds; volatile organic compounds in the groundwater ranged from 10 to 1,000 micrograms per liter. The saturated zone is comprised of silty clay, and the depth to groundwater is approximately 12 feet.

Prior to closure, pond water was neutralized with lime, treated with bacteria for denitrifying, pumped, and treated in a liquid treatment facility. Closure of the ponds consisted of stabilizing the remaining sludge by spreading dolomite shot rock over the bottom of the ponds and by installing an engineered cap consisting of compacted clay, a poly vinyl chloride liner, a geosynthetic drainage net, a filter fabric, and a vegetative layer. Pond water was treated from 1983 through 1986 by Martin Marietta under an operation and maintenance budget.

Remedial design and construction, conducted by Rust Engineering under contract to Martin Marietta, took place from November 1987 to November 1988. Cost estimates were made by Martin Marietta Energy Systems and Lockwood Greene Engineers and reviewed by Martin Marietta Energy Systems and Lee Wan & Associates.

The total cost of S-3 Pond closure, not including water treatment, was $2.283 million, about 3 percent less than the estimated cost of $2.346 million. Field engineers indicated that capping costs at the Y-12 Plant have declined since the S-3 Ponds were capped as a result of improvements in productivity. (S-3 Ponds were the first

Table C-7-Costs Reported for the Y-12 Plant

Total Cost of water treatment (1986 dollars)		
	Actual:	$5.5 million ($0.61/gallon) includes neutralization, biodenitrification, construction of a liquid treatment facility, pumping and treating 9 million gallons of pond water. Construction of the liquid treatment facility cost $1.5 million.
Cost of pond closure (1987 dollars)		
Cost of sludge excavation		
	Estimated:	$78,000
	Actual:	$78,000 ($260/cubic yard)
Cost of sludge stabilization		
Cost of dolomite shot rock		
	Estimated:	$395,000 ($8.78/ton of shot rock)
	Actual:	$347,000 ($7.70/ton of shot rock)
Total cost of stabilization (including dumping and spreading 45,000 tons of dolomite shot rock)		
	Estimated:	$500,000 ($98,000/acre)
	Actual:	$465,000 ($91,200/acre)
Cost of capping 5.1-acre area with 4.2-foot-thick cap (1989 dollars)		
Cost of cap construction		
	Estimated:	$1,325,000 ($259,000/acre; $5.96/square foot)
	Actual:	$1,290,000 ($252,940/acre; $5.81/square foot)
Total cost of cap installation (includes administration, engineering design, and testing)		
	Estimated:	$1,768,000 ($346,670/acre; $7.96/square foot)
	Actual:	$1,740,000 ($341,176/acre; $7.83/square foot)

SOURCE: Office of Technology Assessment, 1990.

area capped.) Cost estimates and cost breakdowns were not available for water treatment activities because the work was carried out by Martin Marietta under general operating and maintenance task, and was not recorded as environmental restoration. Estimates provided for the closure were based on the remedial action project description; the 30 percent, 60 percent, and 90 percent design reviews; and subcontractors' bids.

Oil Lund Farm (see table C-8)-The Oil Land Farm comprises a 13-acre area that received machine coolants and waste oil, some uranium-contaminated, from 1973 to 1982. (Other areas in the land farm are also undergoing closure, but they are not included in this analysis.) The land farm was designed to promote the biological degradation of this waste through the application of nutrient-adjusted soil. Prior to closure, the area contained contaminated soil and groundwater.

Closure of the site consisted of the removal of 390 cubic yards of PCB-contarninated soil, which constituted all of the soil with PCB concentrations in excess of 25 ppm. Other contaminants included solvents and radioactive materials, but no cleanup standard was specified for them. No information is available on the levels of these other contaminants. Soil is being stored in a vault for future disposal. The area was then covered with an engineered cap.

The remedial design and construction period extended from February 1988 through September 1989. Cost estimates were prepared by Martin Marietta Energy Systems and Lockwood Greene Engineers and reviewed by Martin Marietta Energy Systems and Lee Wan & Associates.

The total cost of closure amounted to $3.16 million, including the costs of administration, design, road construction, stream diversion, and vault construction. Cost breakdowns were provided only as shown.

Oak Ridge National Laboratory (ORNL)

Remediation work at ORNL has been minimal. However, a series of technology demonstration projects have been carried out at Solid Waste Storage Area 6 (SWSA 6) that are similar to activities carried out elsewhere. The total ER budget for ORNL in the 1989 Five-Year Plan was $601 million.

SWSA 6 (see table C-9)

SWSA 6 covers a 68-acre area, about 15 acres of which were used for waste disposal. The area has been in use since 1973 and contains waste in unlined trenches and auger holes. The waste includes low-level solid radioactive waste, solvents, scintillation liquids, Laboratory glassware and equipment, protective clothing, obsolete mechanical equipment, construction materials, asbestos, filter media and resins, animal remains, and contaminated

Table C-8-Costs Reported for the Oil Land Farm (1988 dollars)

Cost of excavation	
Actual:	$18,000 ($46.15/cubic yard)
Cost of vault construction	
Actual:	$250,000 ($833/cubic yard capacity)
Cost of backfilling and contouring	
Cost of soil	
Actual:	$36,000 ($1 55/cubic yard)
Cost of contouring	
Actual:	$239,000 ($18,800/acre)
Cost of cap installation (including administration, design, etc.)	
Estimated:	$3,240,000 ($249,23/acre; $5.72square foot)
Actual:	$3,160,000 ($243,076/acre; $5.58/square foot)

SOURCE: Office of Technology Assessment, 1990.

earth. These disposal areas are now in the process of characterization; the total volume and nature of contamination are as yet unknown. Currently, SWSA 6 is used for the disposal of low-level radioactive waste in concrete silos and above-ground tumuli. Through May 1986, approximately 312,000 cubic feet of low-level waste containing more than 200,000 curies of radioactivity was buried at SWSA 6.

Groundwater in the area is very close to the surface, occurring in the lithologically heterogeneous Conasauga Group. The soil is generally characterized as strongly leached, low in organic matter, and silty, although considerable amounts of clay maybe present. In addition to the city of Oak Ridge, four communities are within 10 miles of the site. Public involvement in ER activities has been low to date but is expected to increase during the remedy selection process. The RFI of SWSA 6 was scheduled for completion in September 1990. Final closure is expected to be completed in FY 1993. An interim cap consisting of an 80-mile high-density polyethylene liner has been placed over the site until final closure is begun.

The Tennessee Department of Health and Environment has regulatory authority over the RCRA closure of SWSA 6; however, radioactive contamination will be covered by CERCLA under a pending FFA. Cleanup goals have not yet been determined but will be developed as part of the RFI.

Existing cost estimates for the closure of SWSA 6 are based on preliminary evaluations of potential remedies. These estimates were made by Martin Marietta, but they have not been reviewed or validated.

The final remedy for SWSA 6 has not yet been chosen. The grouting demonstration project indicated that the trench voids could be successfully filled, thereby eliminating subsidence. The dynamic compaction project indicated that compaction also reduced the void space considerably.

Table C-9-Costs Reported for SWSA 6 (1989 dollars)

Costs of groundwater monitoring wells
- Cost of well installation (shallow wells, 2-inoh diameter; deep wells, 4-inoh diameter)
  - Estimated: $22,500 to $25,000 per well
  - Actual: $22,147 per well (about $340/foot for 65-footaverage depth)

Annual cost of sample analysis
- Estimated: $1,740 per well

Annual operating and maintenance oost
- Estimated: $320 per well

Cost of interim capping
- Cost of cap installation (includes planning, management, design, and construction; health, safety, and environmental monitoring)
  - Estimated: $3 million
  - Actual: $3 million ($288,461 /acre; $6.62/square foot) (construction only $1.4 million; $3.09/square foot)

Annual cost of cap operation and maintenance
- Estimated: $104,000 ($0.23/square foot)

Annual monitoring cost
- Estimated: $150,000 ($0.33/square foot)

Cost of grouting demonstration project (The voids in Trench 150 were grouted using 30% Portland cement, 55.5% eastern class C fly ash,5.5% sodium bentonite, and 0.02% glucono-delta-lactone at 12.5 pounds/gallon of water. Total injected= 8,081 gallons.)
- Cost of materials
  - Estimated: $2,000
  - Actual: $1,697
- Cost of equipment mobilization
  - Estimated: $10,000
- Cost of grouting process
  - Actual: $48,680 ($6.05/gallon)
- Cost of scientific evaluations
  - Estimated: $100,000
- Cost of commercial grout application
  - Estimated: $2.60/gallon of grout emplacement

Cost of dynamic compaction demonstration project (test on Trench 271; 64 square meters (690 square feet), 4.06 meters deep (13 feet), consisting of low-level radioactive solid waste components; compaction achieved with a 60-ton crane)
- Cost of site preparation
  - Estimated: $1,000
- Cost of equipment mobilization
  - Estimated: $3,500
- Dynamic compaction operation and maintenance cost
  - Estimated: $3,000 ($4.35/square foot)
- Cost of scientific evaluation
  - Estimated: $100,000

SOURCE: Office of Technology Assessment, 1990.

Idaho Operations Office (ID) (see table C-10)

The Idaho Operations Office oversees the activities at INEL and the Grand Junction Projects Office. According to ID and EG&G Idaho personnel, the only completed remedial action at their facility is the capping of a waste injection well. Information was requested, but not available, on the Chemical Processing Plant gravel pit and tank farm closing and the SPERT IV waste removal and remedial action.

The initial 1989 Five-Year Plan estimates for ID were made by EG&G personnel (including a financial manager and an environmental engineer). These estimates were reviewed and amended by DOE and EG&G reviewers, but no documentation is available for either the initial or the amended estimates. The total ER funding identifkd for ID for FY 1989-95 was $707.9 million, according to the 1989 Five-Year Plan.

The capping of the CPP injection well was initiated in October 1989 and completed in November 1989. Remediation was designed by EG&G and WINCO in February 1989 and undertaken by M&K with the supervision of WINCO. The 468-foot injection well had been used for the disposal of liquid waste. Remediation consisted of perforating the well casing with explosives and tilling the well with cement in stages. The total actual cost of the

Table C-IO-Costs Reported for the Idaho Chemical Processing Plant

Monitoring well installation

Cost of well installation (two monitoring wells at the CFA landfill, both 8-inch diameter with stainless steel casings in saturated zone—combined depth 1,186 feet); (1989 dollars)
Estimated: $257,000 ($217/foot)
Actual: $331,000 ($279/foot)

Cost of well installation (four 8-inch diameter wells 500 to 700 feet deep to be drilled at the central landfills) (1990 dollars)
Estimated: $200,000 per well ($286 to $400/foot)

Cost of sample analysis (quarterly sampling for four wells); (1989 dollars)
Estimated: $75,000 per year ($4,687 per sample)
Actual: $82,000 per year ($5,125 per sample)

Cost of well operation and maintenance (1989 dollars)
Estimated: $5,000/year

Additional costs (including health and safety plans, quality assurance/quality control, and technical work plan; 1989 dollars)
Estimated: $40,000
Actual: $60,000

SOURCE: Office of Technology Assessment, 1990.

remediation was reported at $558,278, including design and construction but excluding the salaries of supervising WINCO personnel.

Increases in monitoring well costs resulted from problems encountered during drilling, including heaving sand, grouting of wells, and use of bentonite seals. Sampling costs have been steadily increasing due to the limited availability of qualified laboratories. Samples are sent from Idaho to St. Louis for analysis and often require at least 8 weeks for results.

Lawrence Livermore National Laboratory (LLNL)

LLNL (see table C-n) is managed by DOE's San Francisco Operations Office (SAN), along with a number of other facilities. The total ER funding identified for SAN in the 1989 Five-Year Plan for FY 1989-95 was $218.2 million. LLNL contains two general areas of contamination: 1) the main Livernnore site, which is now listed on the National Priorities List (NPL), and 2) Site 300. The 1989 Five-Year Plan estimate amounted to $55.9 million for the Livermore site cleanup over FY 1989-95 and to $30.75 million for the Site 300 cleanup during that same period (not including an additional $12.2 million for Site 300 environmental assessment activities during that same period). The level of confidence for both estimates was reported as moderate or at the conceptual design stage. Environmental investigation and remediation efforts have been underway at LLNL, under the direction of the California Regional Water Quality Control Board (RWQCB) San Francisco Bay Region and the Califomia Department of Health Services (DHS) since 1983. Activities at LLNL are now coordinated under an FFA with EPA, RWQCB, and the Califomia DHS. Information is not available on the methodology used by LLNL to estimate ER costs.

Livermore Site

The Livermore site comprises about 700 acres (1.1 square miles), beneath which the groundwater is contaminated with volatile organic compounds (VOCs). Contamination is the result of leaking tanks and drums that had been disposed of in the area and from use of the area as an aircraft maintenance facility by the U.S. Navy. Between 1983 and 1989, $25.2 million was spent on characterizing and cleaning up the site (5). It is now believed that about 2 billion gallons (7.5 billion liters) of groundwater is contaminated above the 1-ppb level with VOCs; the amount of contaminated soil, in "hot spots" around former leaking tanks and drums, has not been calculated. The depth to groundwater at the site ranges from about 30 feet in the northwest to about 110 feet in the southeast. Perchloroethylene and lower concentrations of other VOCs have been detected in offsite monitoring wells. A groundwater plume containing VOCs appears to be migrating from the southwest comer of the site to the west-northwest, at a rate of about 100 feet per year. A public water well system serving 10,000 people is within 3 miles of the contaminated groundwater.

The saturated zone can be described as alluvium, consisting of sandy silt to silty sand with some gravel layers. Fault zones are present several hundred to several thousand feet to the south and east of LLNL. The closest populated area is about 0.1 mile from LLNL.

Prior to groundwater remediation, two cleanups were done at the Livermore site: 1) removal of a former landfill at East Traffic Circle in 1984-85 and 2) excavation of former waste pits and evaporation ponds in the Taxi Strip Area in 1982-83. Engineering design for groundwater remediation is not expected to be completed until FY 1992; planned remediation will consist of extraction and treatment by an ultraviolet/peroxide process combined with air stripping polish. Cleanup goals will be the maximum contaminant levels (MCLs) for individual VOCs and fuel hydrocarbons, and below MCLs for tritium (20,000 picocuries per liter), chromium (50 ppb), and lead (50 ppb). Cost estimates for groundwater remediation have been provided through LLNL by Weiss Associates and are based on two pilot groundwater remediation projects undertaken at the site. Remediation is expected to take 20 to 30 years to complete.

Summary

From the above descriptions of cost estimating methodologies, it seems clear that the cost estimates in the 1989 Five-Year Plan were inconsistent and difficult to compare among facilities. Although steps are being taken by both

Table C-n-Costs Reported for LLNL (1989 dollars)

Groundwater monitoring wells (No actual costs were provided, only estimates, although 300 monitoring wells have been completed.)

- Cost of installation (50 to 300 feet deep, 4.5 inch diameter)
  - Estimated: $20,000 per well plus $2,000 for soil and drilling mudsamples (additional mobilization/demobilization costs estimated at $1,200 per well)
- Annual cost of water sample analyses
  - Estimated: $400,000 for 300 wells ($1,333 per well)
- Annual cost of well operation and maintenance
  - Estimated: $50,000 for 300 wells ($167 per well)

Groundwater remedlation (planned; all rests estimated)

- Number of wells planned, by type
  - Extraction: 20
  - Recharge: 2 to 3
  - Piezometers: 100
- Cost of well installation, by type
  - Extraction: $50,000 per well (50 to 200-foot depth; 6-inch diameter)
  - Recharge: $65,000 per well (400 to 500-foot depth; 8-inch diameter)
  - Piezometers: $10,000 per well (50 to 200-foot depth; 2-4-inch diameter)
- Annual cost of sample analysis
  - Total: $275,000 (about $2,200 per well); (Frequency of water sampling is generally quarterly; various clean wells and wells well within the margins of the plume are sampled on a semiannual or annual basis.)
- Annual well operation and maintenance cost, by type
  - Extraction: $10,000 per well
  - Recharge: $15,000 per well
  - Piezometers: $1,000

Cost of treatment tacilities (Total volume treated will be about 400 gallons/minute for the site; the number of treatment facilities is estimated at seven.)

- Treatment facility instruction cost
  - Per facility: $400,000
- Treatment facility annual operation and maintenance cost
  - Total: $75,000

Method of wastewater disposal (recharge via recharge basin and recharge wells; infiltration in arroyos; total of 400 gallons/minute)

- Cost of disposal: $1,150,000
- Cost of decommissioning wells and treatment facility
  - Wells: $7,000 each
  - Treatment facilities: $300,000 ($400,000 if underground piping removed)

SOURCE: Office of Technology Assessment, 1990.

DOE and its prime contractors to address this inconsistency, the costs in the 1990 Five-Year Plan are also of a very tenuous nature. As the above case studies show, costs for similar activities, both estimated and actual, can vary significantly from facility to facility, and even from site to site (see table C-12).

Because data are extremely limited and so few remedial actions have actually been completed, it is difficult to draw any valid conclusions from this variation. Variations in costs may be the result of legitimate differences in circumstances at each facility. The experience with unit costs of remedial action in the Superfund program has been similar. The implications are that it is very important to keep good records of costs, project characteristics, implementation, problems encountered, and other factors impacting costs to assess the efficiency and effectiveness of DOE's Environmental Restoration Program. Such careful attention to costs appears to have been lacking in the early years of the Superfund program (and may even continue), making it extremely difficult to determine its success and opening EPA to a barrage of criticism. Careful attention to unit costs can be most valuable if initiated early in a program.

With respect to the ability of DOE and its contractors to estimate costs of remedial action, no conclusions can be drawn from the above information. The availability of both estimated and actual costs has been limited to some extent because of the way in which some of the remedial activities were funded In many cases, cleanup or operation and maintenance work was done under an operating or central services budget (for example, water treatment of the S-3 Ponds at Oak Ridge). When this

Table C-12—Unit Cost Comparison: 11 DOE Case Studies (costs in 1989 dollars unless otherwise noted)

Activity/site	Groundwater monitoring well installation per foot	Sample analysis per well, annual	Monitoring well annual operation and maintenance per well	Soil/sludge excavation	Soil transportation per ton-mile	Soil disposal	Groundwater recovery well installation per foot	Sample analysis, per sample	Recovery well operation and maintenance per well, annual	Treatment facility construction, total	Cap installation, per square foot	Cap operation maintenance per square foot per year
4.5-acre site (Pinellas-AL)	$150	—	—	$66/ton (1986 dollars)	16.5 cents (1986 dollars)	$110/ton offsite (1986 dollars)	$228	$192 (e)	$1,875 (e)	$50,000 (e) ($3,333 per million gallons annual capacity)	—	—
002 outfall (Kansas City-AL) .	—	—	—	$8/ton; $11/cubic yard (1988 dollars)	9 cents (1988 dollars)	$146/ton; $184/cubic yard offsite (1988 dollars)	—	—	—	—	$0.42 (top soil and clay) (1988 dollars)	—
183-H solar basins (RL)	$417	$11,500	$2,750	$2,084/cubic yard (includes packaging)	—	$795/cubic yard (shortage)	—	—	—	—	—	—
M-Area settling basin (SR)	—	—	—	—	—	—	$8.47/cubic yard (1986 dollars)	—	—	—	$6.85 (with backfill) (1986 dollars)	$0.10 (e) (1986 dollars)
A/M Area ground-water remediation (SR) ...	$132 (e)	$2,600 (e)	$15-30 (e)	—	—	—	$159 (1985 dollars)	$1,000 (e)	$9,000 (e)	$4.865 million (1985 dollars)	—	—
Mixed waste management facility closure (SR) ...... —	—	—	—	—	—	—	—	—	—	—	$7.63	—
S-3 Ponds closure (Y-12, OR)	—	—	—	$260/cubic yard (1987 dollars)	—	—	—	—	—	$1.5 million (1986 dollars) $7.83	—	—
Oil landfill closure (Y-12, OR)	—	—	—	$46/cubic yard (1988 dollars)	—	—	—	—	—	—	$5.58 (1988 dollars)	—
SWSA 6 closure (ORNL, OR)	$340	$1,740 (e)	$320 (e)	—	—	—	—	—	—	—	$6.62	$0.56
INEL (ID)	$286-$400 (1990 dollars) (e)	$20,500	$1,250 (e)	—	—	—	—	—	—	$2.8 million	—	—
LLNL (SAN)	—	1,333 (e)	$167 (e)	—	—	—	$400 (e)	$2,200/well/ year (e)	$10,000 (e)	$400,000/ facility (e)	—	—

(e) = estimated costs

NOTE: All of these costs were submitted for DOE review at each applicable facility; no comments were received from the Richland Operations Office.

SOURCE: Office of Technology Assessment, 1990.

occurred, it was impossible to separate the costs of remedial activities from normal operating costs of the facility. With accounting procedures for waste management and environmental restoration still in an apparent state of flux, it is not possible to determine if this situation will change. For some activities, it may be very difficult to separate the costs of environmental restoration, waste management, and defense production activities.

From the limited information obtained in this analysis, no consistent relationship between estimated and actual costs has become apparent.[10] Cost overruns have apparently been due primarily to lack of detailed characterization of the contamination, especially with respect to volume, or to unforeseen circumstances, such as unusually high rainfall. Costs were also overestimated (for Savannah River's MWMF) and estimated accurately (A/M area groundwater remediation).[11] Based on EPA Superfund experience, cost overruns of as much as 100 percent for remedial action have not been unusual (6). Closer attention to the details of current remedial action costs may help in estimating future costs, but wide variation can still be expected due to the uncertainties inherently associated with contaminated waste sites.

OVERVIEW OF THE DEPARTMENT OF ENERGY COST ESTIMATION PROCESS

Past Estimation Practices and Consistency of Five-Year Plan Estimates

DOE has a well-established process for the estimation and review of cost for major construction contracts. (This process is regularly applied to "line item" projects and is generally followed, with more limited review, for smaller construction projects.) All requests for proposals for construction work include detailed instructions specifying how cost estimates are to be provided for specific types of contracts and services. These guidelines are set out in DOE orders and supplemented by field office guidelines and orders based on Federal Acquisition Regulations, which include basic cost accounting principles in sections 30 and 31, and on the DOE Supplemental Acquisition Regulations.

Each DOE operations office has access to its own cost estimators, who are usually employed by the management and operations contractor. These estimators all follow the same basic cost guidelines. However, because of the uncertain nature of cost estimation and the flexibility of the guidelines (which is necessary to allow for this uncertainty and the variability among sites), different cost engineers/estirnators may interpret the guidelines differently.

DOE headquarters has an independent cost estimators group, which reviews cost proposals to determine the probable costs of services and reviews mod.iilcations to contracts both for headquarters and for field offices. Line item project costs are regularly submitted to the independent cost estimators at DOE headquarters. In the event of a disagreement or large discrepancy, management makes a determination based on the evidence.

It must be emphasized that this procedure has been used for all projects in the past with regularity, except ER projects. The cost guidelines used for typical construction/service contracts are not fully compatible with environmental remediation projects. This incompatibility arises for two major reasons. First, the work breakdown structure for construction projects is not entirely transferable to environmental restoration projects because of the differences in the kind of work being done. Second, regulatory requirements for ER projects include a number of items, such as public involvement, that might not normally appear in a construction contract and are not accurately reflected in construction work breakdown structures.

Partially for these reasons, DOE cost estimators have not routinely been involved in estimating costs for ER projects and have generally been excluded from estimating costs that appear in the Five-Year Plan. Estimates in the 1989 Five-Year Plan were often prepared by contractors, or subcontractors, and compiled by DOE engineering or environmental staff in what has been described by some as a "seat of the pants" manner.

According to information gathered on the methodologies used to prepare cost estimates for the 1989 Five-Year Plan, no degree of consistency appears to exist among estimates for the various field offices, and little may even exist among estimates for different sites within each field office's area of responsibility. Field offices were given limited time to prepare the initial estimates, and these were often done on an ad hoc basis. Several field offices attempted to develop a more methodological approach. One example of such an attempt is the Albuquerque Operations Office, whose estimation strategy is described above. Even there, however, some facilities (i.e., Rocky Flats and Kansas City) opted to prepare their own estimates for the 1989 Five-Year Plan. The precise methods used at those facilities have not been documented. Apparently, DOE headquarters issued no

[10] Cost variation has been studied for environmental remediation projects by IPA, Inc., under contract to DOE. The studies conclude that about 75 percent of the variation can be explained by project definition, site complexity, and level of sophistication of cleanup technology.

[11] Although cost estimates for the A/M groundwater project accurately reflect expenditures for the plant equipment installed, the initial design was insufficient because of incomplete characterization and additional equipment was required (see app. B).

guidance for the estimation of costs for the 1989 Five-Year Plan.

In the 1990 Five-Year Plan, some further attempts have been made by individual field offices to develop a more consistent approach to cost estimation. Greater effort has been devoted to providing estimates that can be better justified with supporting data. This increased attention has arisen from realization that the Five-Year Plan estimates will be used for budgeting purposes. Conversations with field office personnel throughout the DOE Nuclear Weapons Complex indicate that the original estimates were made without this understanding. In many cases, the 1990 cost estimates, particularly for site characterization, are higher than those that appeared in the 1989 document. Field office personnel claim that this is the result of more information about characterization needs and more detailed analysis. Field offices have been pressured by DOE headquarters to reduce their 1990 cost estimates to the lower, less carefully constructed 1989 estimates.

Some field office personnel have also indicated that pressure is being exerted to reduce time and expenditure on characterization and to hasten the start of remediation. This pressure appears to be coming both from public interest groups and from DOE headquarters.

With regard to the 1990 Five-Year Plan, it should be pointed out that many of the reporting codes have been changed. In the development of budget numbers, there was some confusion regarding the designation of activities as waste management or environmental restoration. This confusion appears to result from conflicting and changing guidance from DOE headquarters, which may make comparison of aggregate budget numbers difficult.

Current Efforts To Standardize Environmental Restoration Cost Estimation Practices

The need to create consistency among cost estimates for environmental restoration has been recognized by some DOE staff, both at headquarters and at field offices. The Environmental Restoration and Waste Management Cost Assessment Team (EM-CAT) has been meeting since about mid-1988 in an effort to develop standardized cost estimation tools and techniques. Members of the team are primarily cost engineers, but environmental engineers and other related professionals have also attended meetings on an ad hoc basis. EM-CAT's goal is to provide a focal point for the dissemination of costing data, methodologies, and techniques (7).

The CAT guidelines provide work breakdown structures for remedial activities, including RIs, FSS, remedial design, and remedial action. The attitude of the cost engineers is rather conservative, in that they seem reluctant to diverge from past practices, but they also recognize the need for new guidance for environmental projects. Some disagreement exists among team members about how close the connection should be between past estimating practices and newly developed guidelines. In addition, from the comments made by some CAT members, it is evident that not all members are in agreement about the degree of importance of this effort. Apparently, the issue of consistent cost estimates is receiving some increased attention at DOE headquarters.

In the course of designing new cost estimation guidelines, DOE headquarters contracted with IPA, Inc., to prepare a database of environmental cleanup costs to help determine the level of economic risk associated with these activities (i.e., the probability that actual costs will differ significantly from estimated costs).

One of the difficulties in estimating remediation costs is that a historical database, similar to that which exists for construction projects, is not available. As far as can be determined, this database is the only concerted effort by DOE to develop a historical database for its remediation activities. Even then, the contractor (IPA) apparently has had difficulty collecting data on recent DOE remediation. Cost accounting methods for these DOE projects have not lent themselves to the creation of such a data base. Several interested parties suggested that the creation of a unit cost accounting system for environmental activities would prove extremely useful for future cost estimation efforts. (Interestingly, EPA also has no standardized unit cost accounting method for CERCLA or RCRA cleanups. It was claimed by a member of the EPA staff present at the La Jolla CAT meeting that no one can agree on the standard elements of cost that should be collected, so no effort is being made.)

Other work performed by EM-CAT has included a review of currently available data bases and cost estimation models used for estimating costs of remediation by other entities. Several such models have been identified, although none address radioactive and mixed waste. Two Federal agencies have developed or are developing remediation cost estimation models. The Army Corps of Engineers, motivated by its responsibilities related to CERCLA sites, is in the process of developing a model and database patterned after its construction cost estimation model, the most recent version of which has been in use for about 8 years. The Corps is developing a CERCLA estimating manual, a standard code of accounts (it reiterated that standard construction codes do not work for CERCLA), and a cost estimation checklist. This guidance will be used at the final engineering design phase of the projects (i.e., after feasibility studies have been done and remedial technologies have been selected). This model does not include radioactive and mixed waste and requires very detailed information.

EPA has two models for cost estimation. The Cost of Remedial Action (CORA) model was developed for EPA headquarters to estimate costs for CERCLA out-year budgeting and is applied at relatively early stages of site investigation (8). The model, developed at a cost of $2.5 million, consists of an expert system module, which asks questions about the site characteristics and identifies appropriate remediation technologies, and a cost estimation module, which develops a cost estimate for the selected technologies from its built-in cost database. Again, this model is not designed to address radioactive and mixed waste. IPA, in cooperation with the Los Alamos National Laboratory (LANL), under contract to DOE, performed a validation of the CORA model and found that it chose the technologies ultimately selected for the site at least 73 percent of the time and performed best for removals (9). In general, CORA overestimates costs and has an accuracy of from +50 percent to -30 percent. LANL staff have proposed building a similar model to include radioactive and mixed waste remediation. That effort has not been funded by DOE.

EPA's Cincinnati research office is in the process of developing the Remedial Response Construction Cost Estimating System, called PRACES, to be used as a tool for cost estimation at CERCLA sites (10). The model can calculate costs at early investigation stages up to the final engineering design phase. The model can develop budget estimates for planning purposes, compare costs of alternative remediation technologies, calculate specific site cleanup costs, check cost estimates prepared by others, and conduct present-worth analyses.[12] The model has been in development for about 3 1/2 years at a cost of about $400,000. Limited resources have been devoted to development of the model, thus slowing progress. The model has apparently never been validated; although EPA sent out copies for testing, it did not receive any feedback.[13] Early in 1990, the model developers began communications with the Corps of Engineers concerning a cooperative effort to exchange cost information. Discussions have also begun between EPA and DOE to address the costs of radioactive and mixed waste, but DOE has not been willing to sponsor this effort.

POTENTIAL FOR FUTURE COST SAVINGS FROM RESEARCH AND DEVELOPMENT

DOE has stated that new technologies on the horizon for environmental restoration have the potential to reduce estimated costs considerably. Inquiry into the justification for this statement indicates that the only attempt to quantify the potential cost saving specifically for DOE exists in the 1989 Draft Applied Research, Development, Demonstration, Testing and Evaluation (RDDT&E) Plan. This was done through an examination of the cost saving potential of new technologies both for remediation and for waste minimization.

The cost savings analysis resulted in the conclusion that "[i]mplementation of new technologies developed under the RDDT&E program can significantly reduce future expenditures, especially in situ treatment and waste minimization" (11). This conclusion is based on three cost savings analyses: in situ treatment of a waste site at the Hanford Reservation, a CORA model comparison of remediation of a low-level waste burial site by excavation/disposal and in situ measures, and waste minimization technologies for low-level, transuranic, and high-level waste. The plan indicates the key nature of benefit-cost information in technology selection and calls for additional studies to collect this type of information. It does not appear that any such studies have yet been initiated by the newly formed Technology Development Division.

Review of RDDT&E Plan Cost Savings Analyses

The first cost savings analysis was based in part on a study done for Westinghouse Hanford Co. by Science Applications International Corp. (SAIC) in 1987 (12). The analysis indicates an estimated savings of $44 million per site by using in situ vitrification (ISV) rather than excavation, treatment (incineration), and redisposal for the cleanup of an unspecified 100 contaminated sites at Hanford. Thus the total savings estimated at Hanford by using ISV was calculated as $4.4 billion in the RDDT&E Plan. This, of course, assumes that each of the sites is the same size, with similar contaminants, geological characteristics, and moisture content (an important factor in estimating the amount of electricity needed for ISV).

The SAIC cost estimates for ISV were based on applying the technology to a trench 35 feet by 35 feet by 30 feet deep (about 1,361 cubic yards). The estimated cost of $389 per cubic yard "does not include health and safety costs associated with working on radiological sites or the cost of backfilling the depression" (13). For the excavation, treatment, and redisposal cost estimate, SAIC estimated costs on an annual basis and assumed that a total of 163,800 cubic yards of soil would be removed per year. SAIC also assumed that the nature of the contamination would require the construction of a building over the excavation area, equipped with an air ventilation system to maintain negative pressure. Contaminated soil is

[12]According to a brief description of the model provided by H. Goddard, U.S. Environmental Protection Agency, Cincinnati, OH.

[13]EPA is apparently contracting with IPA, Inc., to validate the model and to distribute it to EPA regional offices some time this summer (H. Goddard, personal communication, January 1990).

loaded in drums by using remote handling equipment and is disposed of at an approved site at a cost of $60 per drum. Treatment consists of thermal destruction in a rotary kiln incinerator. SAIC estimated the cost at $365 per cubic yard for excavation and disposal only and at $689 per cubic yard if treatment is included.

According to Geosafe Corp., it is difficult to generalize about the cost of ISV, but Geosafe estimates it at $250-$350 per ton for hazardous waste and up to $1,000 per ton for radioactive waste (at SAIC's estimated soil density of 120 pounds per cubic foot, the latter estimate converts to $1,620 per cubic yard).[14] An additional cost of $35,000-$45,000 for treatability tests must be added as well as mobilization/demobilization costs of about $50,000-$60,000, plus $50-$60 for each mile that the equipment must travel to the site (14). Electricity costs are assumed to be about $0.07 per kilowatt-hour. At these costs, ISV is particularly competitive with incineration at large sites because of the latter's high fixed costs. The long-term stability of ISV is yet to be proved. ISV will be tested in mid-1990 at several hazardous waste sites in the United States under the Superfund Innovative Technology Evaluation (SITE) program (Rocky Mountain Arsenal in Colorado is one of these sites). Given the above information, the generalized estimate of $4.4 billion in savings for the use of ISV at Hanford should be viewed with caution and should not be applied directly to other sites outside the Hanford Reservation. (The plan does not attempt to do this.)

The second cost savings analysis uses the CORA model to estimate the cost of remediating a waste site contaminated with low-level radioactivity and VOCs. The analysis compares excavation and disposal with in situ treatment and confinement, yielding a cost ratio of 10 to 1. The in situ treatment and confinement methods examined in the analysis were soil vapor extraction, soil flushing, and a protective cap. As is mentioned in the RDDT&E Plan, CORA was not designed to include radioactive or mixed waste and the treatment methods examined do not address these kinds of contaminants. In addition, the plan indicates that the estimated cost for soil flushing does not include wastewater treatment, which would increase the cost (and reduce the ratio). This analysis, too, should be interpreted with caution.

These analyses highlight the fact that a limited amount of information is available concerning the cost savings potential of innovative or alternative technologies at DOE-type contaminated sites. Some work is in progress throughout the complex, but demonstration of such technologies has been limited. In a 1988 report, EPA examined the application of treatment technologies at

Box C-1—How Does the Choice of Cleanup Level Affect Costs?

It is intuitively obvious that the cost of cleaning up contaminated soil or water will increase as the cleanup standard decreases. As the contaminant disperses throughout the contaminated medium, it will become more extensive, but less concentrated. More soil will have to be excavated, or more water will have to be pumped as the cleanup standard decreases. What is not obvious, however, is that the cost of cleaning up a given *unit* of contaminant increases as the cleanup standard becomes more stringent. This relationship was shown by Canonie Engineers in their cost estimates to clean up trichloroethylene (TCE) contaminated soils at the McKin Superfund site in Maine. For a TCE standard of 1.0 ppm, the cost to remove a pound of TCE was estimated at $880; for a standard of 0.5 ppm, the cost was $1,340; and for a standard of 0.1 ppm, the cost was $2,480. In general, because of the way contaminants disperse in soil and groundwater, it is believed that the relationship between cleanup cost and cleanup standard may be geometric (although this was not the case for the McKin site).[1]

[1]P. Schumann, "Options for Management of Soil Contamination Problems at Superfund Sites: A Proposed Approach to Setting Soil Cleanup Levels," doctoral thesis, University of California-Berkeley, 1989.

radiologically contaminated Superfund sites and concluded that:

> . . . the costs [of onsite treatment technologies] cannot be estimated reliably for any technology and for any site at this stage, because most of the prerequisite information is not available. It also must be cautioned that many, if not most, of the controlling factors will be site-specific (15).

Despite this caution and the lack of substantive data, a general belief exists among some of the scientists involved that new technologies on the horizon for characterizing and treating radioactive and mixed waste sites will ultimately save money. This optimism may be based in part on the cost information that exists on the use of innovative technologies for hazardous waste sites through EPA's SITE program, among other sources. Whether this experience will be duplicated in the radioactive and mixed waste arena remains to be seen. Almost every description of the costs of alternative technologies used on hazardous waste sites is prefaced with a statement that it is very difficult to generalize about the costs of relatively new technologies because they can vary considerably depending on the specific characteristics of a particular site. One disadvantage of using new technologies is their relative uncertainty with regard to performance. As is shown in box C-1, the level of cleanup

[14]Presentation given by D. Timmons at an EPA sponsored training course on solidification and stabilization technologies in Denver, CO, Jan. 10-11, 1990.

performance required for a site can greatly affect costs. Also, one study of the costs of megaprojects found that the use of new technologies in such projects resulted in 'cost growth, schedule slippage, and performance shortfalls" (16). Although this may not be directly comparable to environmental restoration, it does provide a reminder that the benefits of new technologies may not always be manifested in cost savings, particularly at the outset.

It seems premature, at this point, to try to quantify the potential for innovative technologies to reduce the cost of environmental restoration for DOE waste sites. As one scientist at Hanford said, "there's no silver bullet on the horizon for radioactive and mixed waste" (17).

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