ECONOMIC IMPACTS OF WASTE EMPLACEMENT CONFIGURATION FOR THE POTENTIAL NUCLEAR WASTE REPOSITORY AT THE NEVADA TEST SITE[a]

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The Nevada Nuclear Waste Storage Investigations Project is developing a conceptual design for a potential repository in welded tuff at Yucca Mountain, Nevada. Two different configurations are under consideration for waste emplacement: vertical, with single waste canisters placed in holes in the floor of the emplacement drift; and horizontal, with multiple canisters placed in long holes in the walls of the drift. The cost of these two alternatives varies based on the amount of mining, borehole drilling, muck handling, and repository ventilation required. The difficulty of emplacement and retrieval operations also contributes to a cost differential. This paper presents these relative costs, showing a relative total cost differential of $880 million between the two methods.

INTRODUCTION

The Nevada Nuclear Waste Storage Investigations Project is developing a conceptual design for a prospective repository in welded tuff at Yucca Mountain, Nevada. Two different configurations are now under consideration for waste emplacement: vertical, with single waste canisters placed in holes in the floor of the emplacement drift; and horizontal, with multiple canisters placed in long holes in the walls of the drift. These two configurations are shown in Fig. 1. The differences between these two configurations have been compared on the basis of a cell containing 1,000 canisters of spent fuel.[1] This study considers only the relative total cost of vertical and horizontal emplacement and retrieval.

BASES OF THE STUDY

The repository design is based on projected waste receipts which include BWR and PWR spent fuel, commercial high-level waste, defense high-level waste, West Valley high-level waste, cladding waste, high activity transuranic waste, and hardware waste from fuel consolidation. Table I[2] gives a description of these wastes. These data represent 70,000

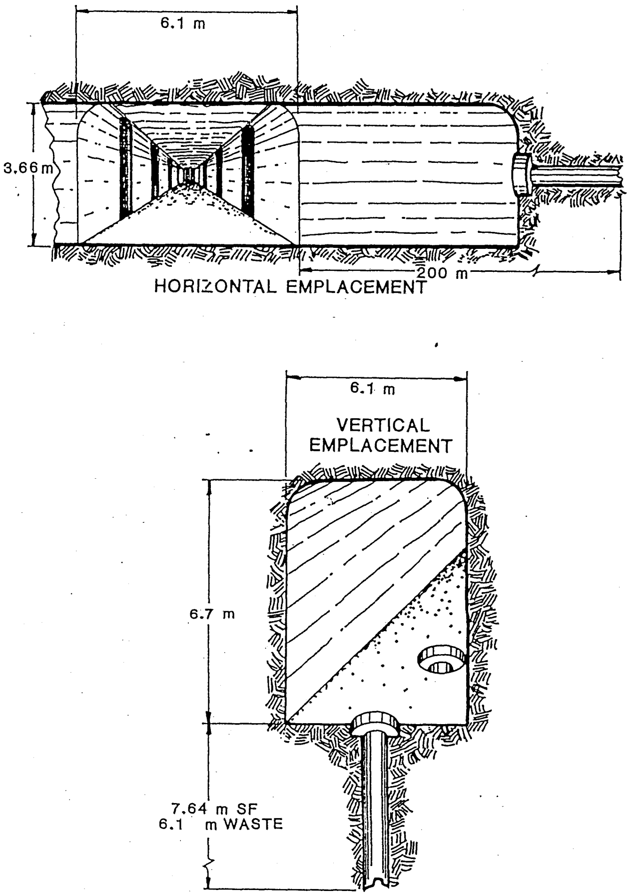

Fig. 1. Waste emplacement configurations.

[a] This work was sponsored by the U.S. DOE under Contract DE-AC04-DP00789.

metric tons of initial heavy metal, 10 years out-of-reactor, divided equally between spent fuel and reprocessing wastes.[a]

TABLE I

Waste Canister Descriptions for the Yucca Mountain Repository

Waste Type	Disposal Canister: Dimensions (cm) OD × Length	Disposal Canister: Weight (kg)	Total Canisters
PWR Spent Fuel	50 × 450	4,500	7,839
BWR Spent Fuel	57 × 450	5,600	4,031
CHLW	32 × 300	800	15,350
DHLW	61 × 300	2,000	6,720
WVHLW	61 × 300	2,000	300
Cladding	61 × 300	1,500	12,290
TRU (reprocessing)	61 × 300	2,000	10,734
Spent Fuel Hardware	61 × 300	2,000	1,932
			59,196

Additional low activity TRU wastes (with surface dose rates less than 200 mr/hr) will be received but these will be emplaced in another manner and are not considered here.

The two configurations will require different underground layouts. For vertical emplacement, a series of long emplacement drifts would be used. For horizontal emplacement, fewer drifts with long boreholes extending out from the drift walls would be used. These underground layouts are shown in Fig. 2. In either case, each hole would be plugged with an inert plug to provide shielding and prevent direct access to the waste. The conceptual design for horizontal emplacement includes a second plug and a steel liner to increase confidence that waste canisters can, if necessary, be retrieved. The hole spacing used results in waste emplacement at an areal power density of 57 kW per acre. Features such as entrance to the repository, service areas, and ventilation shafts would be required for either configuration and are not considered in this paper.

The construction of the underground portions of the repository would involve the mining of emplacement and access drifts, drilling of emplacement holes, ventilation of the drifts, and handling and disposal of mined material. This will also require personnel, equipment, supplies, and facilities to support these activities. In addition to the cost of these items, operating and retrieval costs are included for each configuration. However, repository sealing costs are not reflected in the cost estimate. The sealing of the access shafts and boreholes would be slightly higher for vertical than for horizontal emplacement due to the larger material handling openings required. The difference is felt to be small compared to other costs that have been considered. The extent and nature of any drift backfill has not been determined at this time. However, if complete backfill is ultimately required, the ratio of backfill costs for the vertical and horizontal methods should be comparable to the ratio of the mining costs.

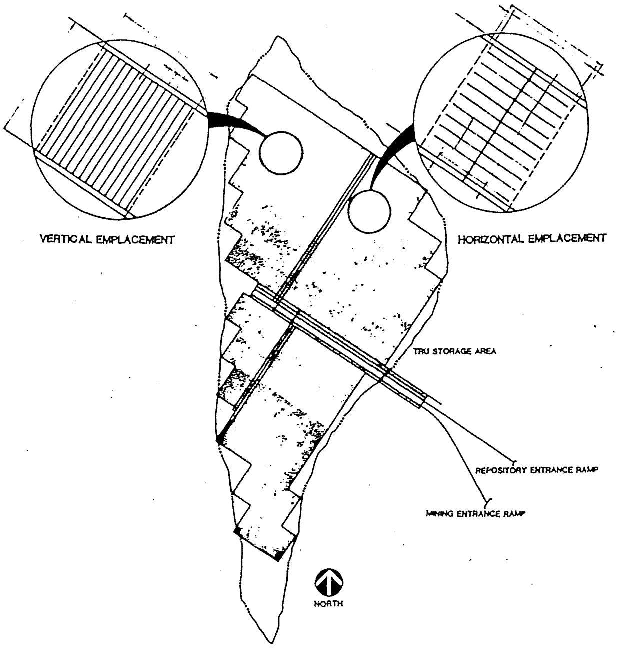

Fig. 2. Preliminary underground layouts.

Vertical emplacement will require more mining, a greater total length of emplacement holes, handling a greater volume of mined material, and, consequently, a larger number of workers and additional equipment and supplies.

Table II gives the amount of mining and drilling and the volume of mined material for the two alternatives.[3]

COST ESTIMATES

Estimated costs for the activities considered here are based on estimates provided by specialty contractors (referenced), the current Davis-Bacon labor rates in effect at the Nevada Test Site,[4] and contractor markups applied in similar DOE projects. Estimates are expressed in 1983 dollars.

ACCESS AND EMPLACEMENT DRIFTS

The cost of drift mining is based on conventional drill and blast methods. Mining costs, estimated by Dravo Engineers,[5] include equipment, materials, and labor and are given in Table III. An average loaded labor rate of $31.20 per hour is applied to construction activites.

[a] This inventory is subject to change based on projected fuel cycle activities in the U.S. nuclear industry. The data used in this study are those available at the time this study was performed.

TABLE II

Mined Material

	Length of Drift	Volume of Drift	Length of Borehole	Volume of Borehole	Total Volume
Horizontal Emplacement	30,000 m	701,000 m^3	233,000	100,000 m^3	801,000 m^3
Vertical Emplacement	304,000 m	11,230,000 m^3	376,000	140,000 m^3	11,370,000 m^3

TABLE III

Drift Mining Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Equipment	$ 25,807,000	$ 2,244,000
Materials	86,656,000	8,307,000
Labor	146,859,000	$23,621,000
Total	$259,322,000	$34,172,000

BOREHOLE DRILLING COSTS

The cost of drilling vertical boreholes is based on the conventional pilot hole drilling and reaming method. The cost of horizontal boreholes is based on a specially designed horizontal boring machine. The costs of these operations estimated by the Robbins Company[6] are given in Table IV. They include equipment, drill cutters and maintenance, overhaul of major equipment, and labor. Cost of muck removal from the borehole, but not from the underground workings, and the cost of the horizontal borehole liner are also included.

TABLE IV

Borehole Drilling Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Capital Equipment	$110,223,000	$19,934,000
Overhaul	12,522,000	4,334,000
Cutters and Maintenance	41,023,000	4,834,000
Labor	33,589,000	14,467,000
Holeliner	---	33,200,000
Holeliner Installation Labor	---	19,500,000
Total	$197,357,000	$96,269,000

MUCK HANDLING

The rock excavated from drifts and boreholes must be transported to the surface and stored for later use as backfill or disposed in an environmentally acceptable manner. The costs of these operations were estimated by Dravo Engineers[5] and are given in Table V.

TABLE V

Muck Handling Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Equipment	$10,208,000	$2,302,000
Repair and Maintenance	55,575,000	4,728,000
Labor	28,355,000	1,771,000
Total	$94,138,000	$8,801,000

VENTILATION COSTS

Ventilation costs are those necessary to provide a safe working environment for mining and waste handling operations. Costs for removing heat generated by the waste, if required, are not included. Ventilation costs will vary during repository (mine) development, during emplacement, and during retrieval, if retrieval is required. The approach to repository ventilation design is to provide two independent systems, one for mine development, and one for the waste emplacement operations. The greater number of drifts in the vertical emplacement configuration requires a larger volume of ventilation air for both the mining and waste emplacement areas.

Table VI gives the ventilation costs for mine development and waste emplacement.[7]

TABLE VI

Repository Ventilation Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Mine Development		
Capital Costs	$ 41,378,000	$ 8,731,000
Operating Costs	111,031,000	23,573,000
	$152,409,000	$32,304,000
Waste Emplacement		
Capital Costs	$ 22,068,000	$ 1,247,000
Operating Costs	40,778,000	20,011,000
	62,846,000	21,258,000
Total	$215,255,000	$53,561,000

The ventilation costs considered here are the capital and operating costs of the ventilation equipment. The capital costs include fans, ducting, etc., and also include the construction costs of ventilation shafts and drifts. Operating costs include power costs, repairs, maintenance, and replacement of worn out equipment. The quantity of air required for subsurface repository construction and operations is based on: a minimum of 110 cfm /bhp for diesel-powered equipment, 20 cfm/bhp for electric equipment, and 210 cfm for every underground worker.

Two types of ventilation are required for retrieval: the cool air required to maintain the drifts at an acceptable working temperature and ventilation to support workers during retrieval operations. Assuming that retrieval is accomplished at the same rate as emplacement, operating costs for the ventilation system during retrieval would be the same as during emplacement. Hickox[8] has calculated cooling requirements for maintaining an acceptable working environment in the drifts. The ventilation costs for retrieval operations are shown in Table VII.

TABLE VII

Ventilation During Retrieval Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Operating Costs		
Drift Cooling	$163,400,000	$ 4,906,000
Ventilation	40,778,000	20,011,000
Total	$204,178,000	$24,917,000

EMPLACEMENT OPERATIONS

Table VIII shows equipment and operating costs for waste emplacement. Operating costs include labor, maintenance of equipment, and fuel. Cost estimates are based on an equipment lifetime of 5 yr and maintenance as estimated by Foster-Miller.[9] Labor for operations is estimated at $28 per hour.

TABLE VIII

Emplacement Operations Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Equipment Costs	$ 37,272,000	$10,930,000
Operating Costs	34,910,000	11,736,000
Hole Plugs	29,598,000	1,166,000
Total	$101,780,000	$23,832,000

RETRIEVAL OPERATIONS

In estimating the costs of retrieval, it is assumed that retrieval occurs at the same rate as emplacement. Retrieval costs are given in Table IX.

TABLE IX

Retrieval Operations Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Equipment Costs	$37,272,000	$10,930,000
Operating Costs	34,910,000	11,736,000
Total	$72,182,000	$22,666,000

FACILITIES

In addition to other direct costs, additional surface facilities are required to support the greater number of employees and pieces of equipment required for mining and operations for the vertical emplacement configuration. Dravo[5] estimates a one time cost differential of $2.3 million for these facilities.

COST SUMMARY

The total relative costs for vertical and horizontal emplacement are given in Table X. The economic impact of industrial accidents is not included in this study.

In summary, horizontal emplacement shows a potential cost savings of $880 million over the vertical emplacement alternative. While development costs for drilling, waste emplacement, and retrieval equipment have not been included in this study, this cost differential should provide a powerful incentive for continued development of horizontal emplacement equipment and operations.

TABLE X

Total Relative Cost Estimates

Cost Element	Vertical Emplacement	Horizontal Emplacement
Mining	$ 259,322,000	$ 34,172,000
Borehole Drilling	197,357,000	96,269,000
Muck Handling	94,138,000	8,800,000
Additional Facilities	2,300,000	
Ventilation		
Mine Development	152,409,000	32,303,000
Waste Emplacement	62,846,000	21,258,000
Emplacement Operations	101,780,000	23,832,000
Total Without Retrieval	$870,152,000	$216,634,000
Retrieval Operations	72,182,000	22,666,000
Ventilation during Retrieval	204,178,000	24,917,000
Subtotal	$ 276,360,000	$ 47,583,000
Total With Retrieval	$1,146,512,000	$264,217,000

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