ANALYSIS OF THE MUA DECISION METHODOLOGY FOR HLW REPOSITORY SITING: PRECLOSURE UTILITIES

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ABSTRACT

Utilities and ranking of the preclosure attributes of the proposed high-level radioactive waste repository are examined, in order to provide insights into the propriety of using this approach for this type of decision and an assessment of the adequacy of the analysis itself. The postclosure utilities obtained in the previous study were greater than 80% for all five sites considered, but showed a greater spread than those in the MUA. The preclosure multiattribute utilities also show a wider spread than in the MUA. The multiattribute utilities are driven by factors in addition to cost of construction; in the MUA, cost of construction is the driver.

PURPOSE OF THE STUDY

In a previous paper (1) the elucidation of the postclosure attributes of the decision-aiding methodology for selecting repository sites for characterization was examined. Scales were constructed for the preclosure attributes which were somewhat more quantitative than those in the MUA and which differed in a few details. The method of multiattribute decision analysis used was that of Keeney and Raiffa (2,3).

The present study examines the utilities and ranking of the pre-closure attributes of the repository. Although the 1987 Amendments to the Nuclear Waste Policy Act have rendered this particular multiattribute utility analysis moot, examination of the analysis still can provide both insights into the propriety of using this approach for this type of decision, and an assessment of the adequacy of the analysis itself. Throughout this paper, Ref. 3 will be referred to as the MUA.

In the MUA, the "constructed scales" used for ecological effects, potential damage to historically significant structures, and aesthetic and socioeconomic effects were drawn by USDOE and contractor experts in the various disciplines involved. Ranking of the sites was done by USDOE and contractor geologists. Single attribute and multiattribute utility functions were elucidated from interviews with five USDOE managers.

The work of Rowe, et al, and others indicates that utility functions are dependent on the individuals involved in drawing them, to a considerable extent (4). Moreover, scales which are not "natural" are constructed subjectively and somewhat arbitrarily. In the previous paper, two general questions were raised about the MUA process:

- To what extent will different experts formulate different constructed scales?
- To what extent do utility functions depend on the individuals constructing the functions?

The present work adds a third question:

- To what extent does any single attribute or subset of attributes drive the decision?

At this writing, it is worth noting that no methodical analysis was used to aid the operative decision to characterize only the Nevada site. This decision was apparently made on the basis of only one attribute, political feasibility (5).

The postclosure utilities obtained in the previous study, shown in Table I, were greater than 80% for all five sites considered, but showed a greater spread than those in the MUA.

TABLE I
Postclosure Utilities Of The Candidate Sites

Site	Utility (USDOE)	Rank (USDOE)	Utility	Rank
Davis Canyon	99.99	1	86.2	1
Deaf Smith	99.98	2	84.1	3
Hanford	99.76	3	82.2	5
Richton	99.99	1	85.0	2
Yucca Mtn	99.98	2	84.0	4

DESCRIPTION OF THE PRESENT STUDY

The MUA constructs scales for the assessment of preclosure performance for aesthetic. biological, archaeological-historical-cultural, and socioeconomic impacts, using input from USDOE and contractor experts (3). The uniqueness and sufficiency of these constructed scales was examined by comparing scales constructed for these impacts by experts in the disciplines in question: professors in the Huxley College of Environmental Studies, whose respective fields of specialization are ethics, history and political science, terrestrial and freshwater ecology, and cultural anthropology, respectively. The scales for aesthetic and historic impact constructed in the present study are entirely different from those in the MUA, but the

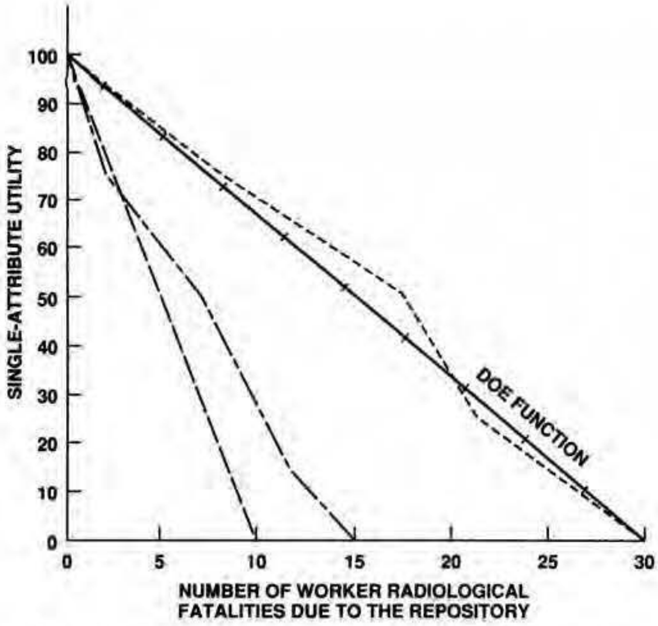

Fig. 1. Utility Function for Worker Health Effects From Radiation Exposure at the Repository.

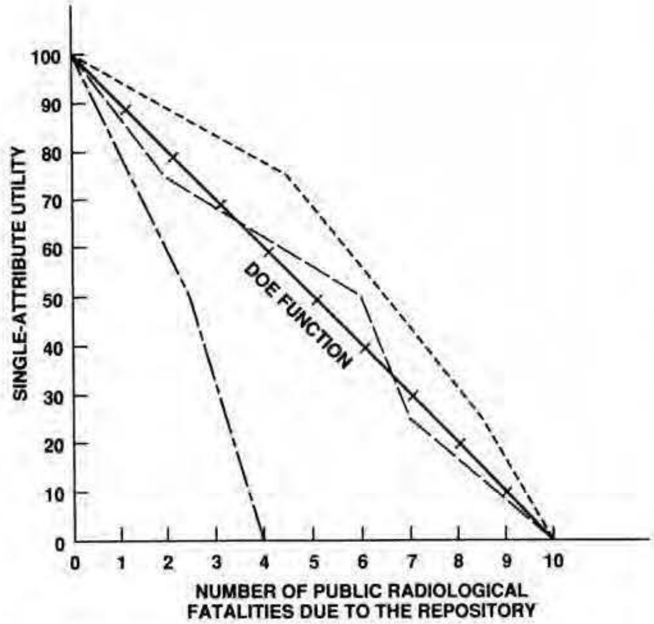

Fig. 2. Utility Function for Public Radiological (Health Effects) From Radiation Exposure at the Repository.

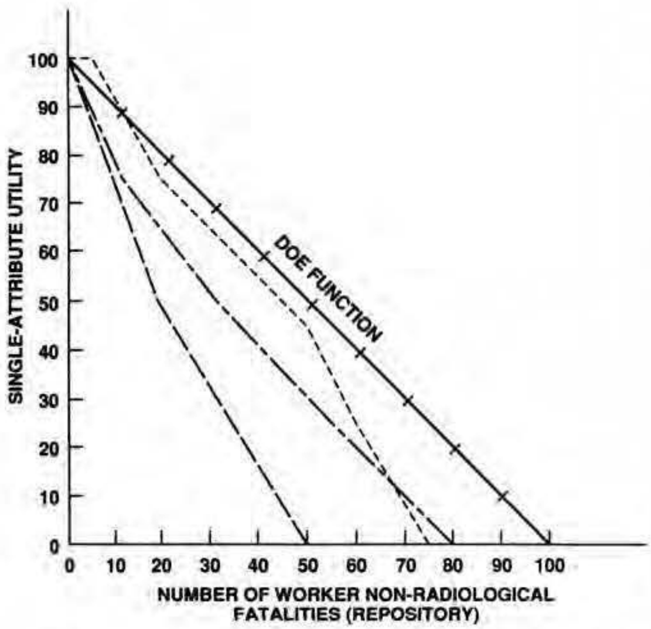

Fig. 3. Utility Function for Worker Non-Radiological Fatalities DOE to the Repository.

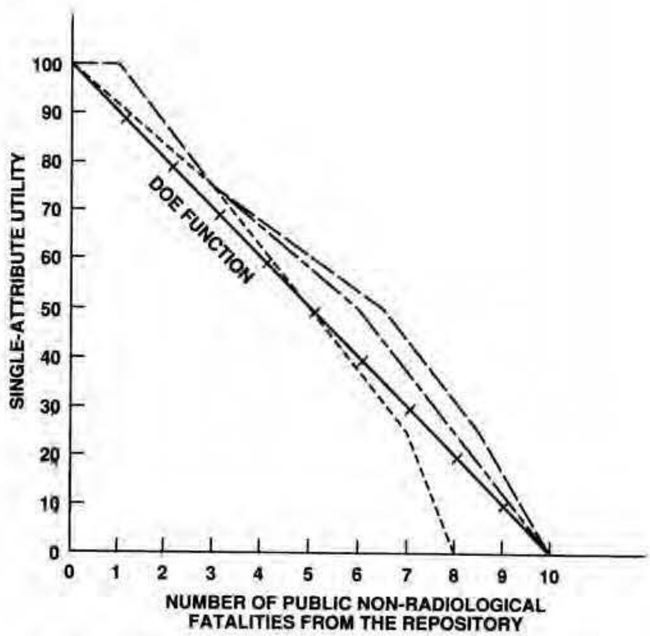

Fig. 4. Utility Function for Public Non-Radiological Fatalities Due to the Repository.

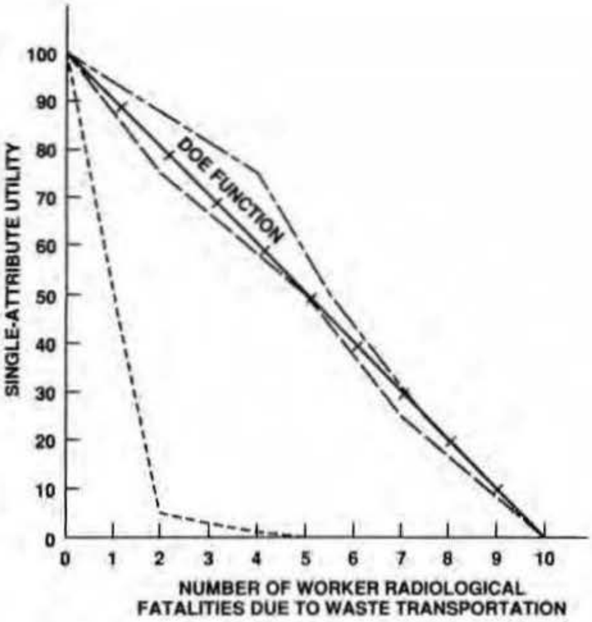

Fig. 5. Utility Function for Worker Radiological Fatalities Due to Waste Transportation.

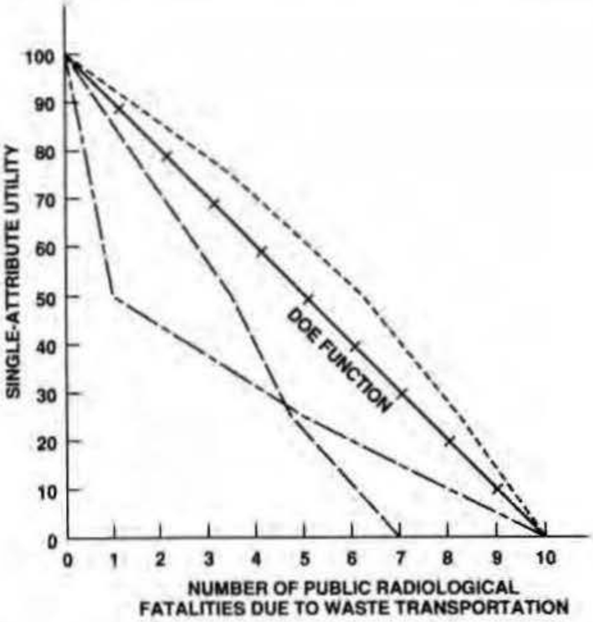

Fig. 6. Utility Function for Public Radiological Fatalities Due to Waste Transportation.

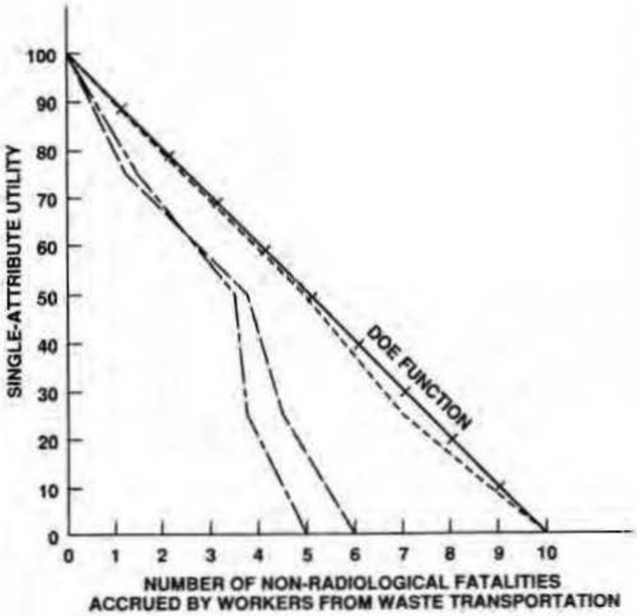

Fig. 7. Utility Function for Worker Non-Radiological Fatalities Due to East Transportation.

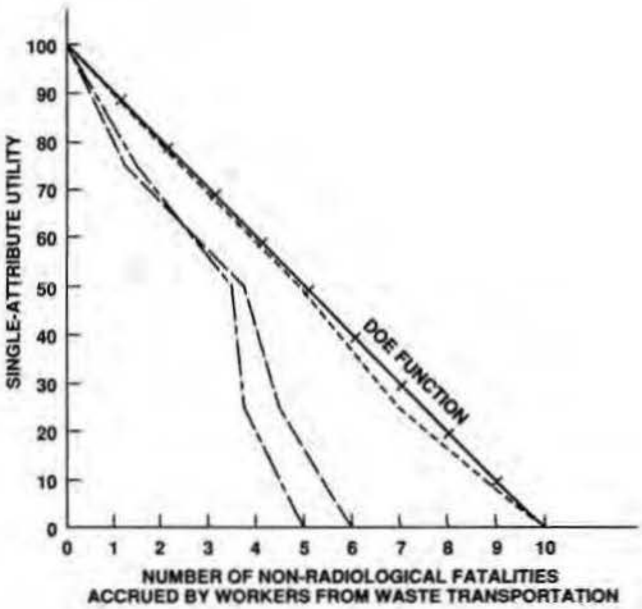

Fig. 8. Utility Function for Public Non-Radiological Fatalities From Waste Transportation.

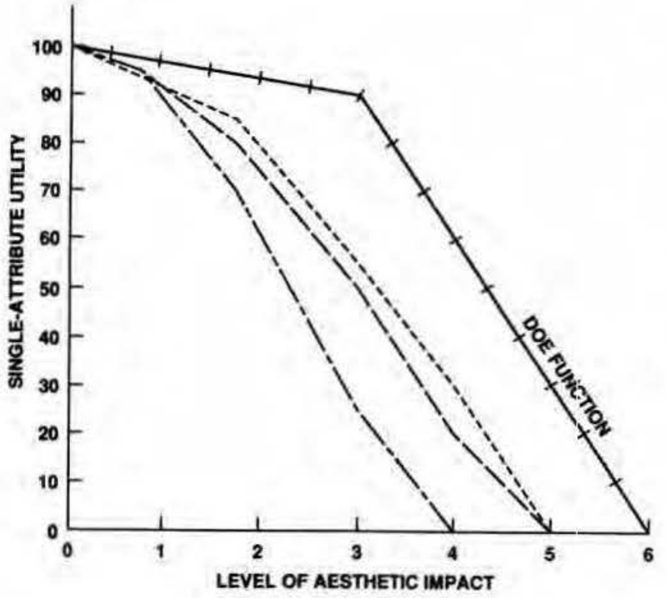

Fig. 9. Utility Function for Level of Aesthetic Impact.

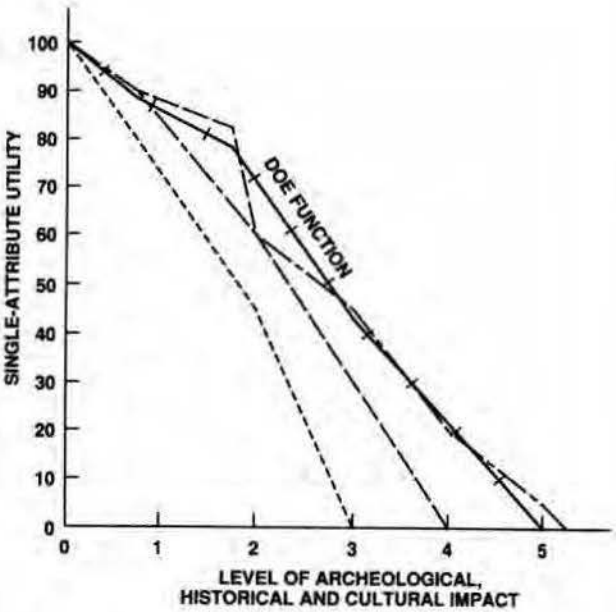

Fig. 10. Utility Function for Archeological, Historical and Cultural Impact.

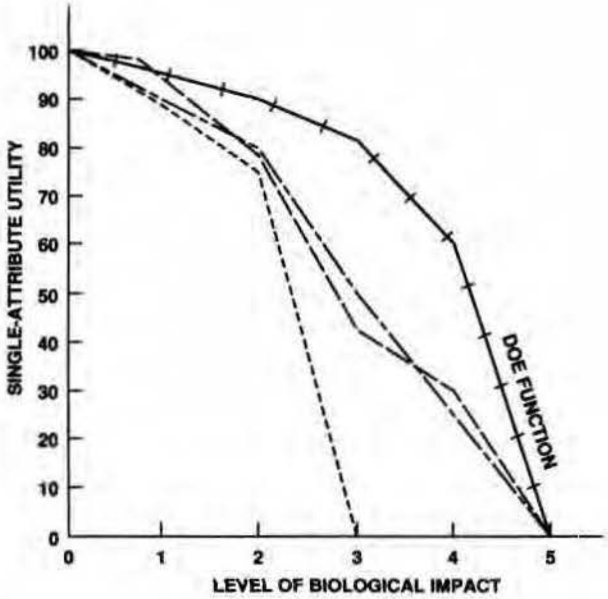

Fig. 11. Utility Function for Biological Impact.

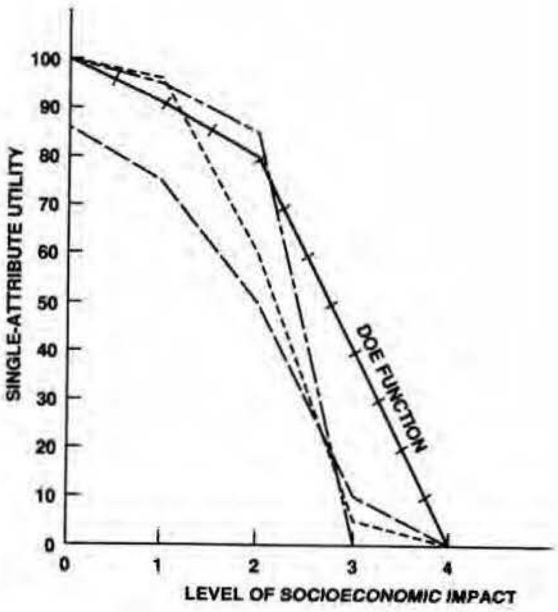

Fig. 12. Utility Function for Socioeconomic Impact.

socioeconomic and biological impact scales consist of additions to the constructed scales in the MUA (1).

The single-attribute utility functions for each attribute were drawn independently by at least three different subjects, and scaling factors were determined in at least three independent determinations for each factor. The utility functions were drawn, and scaling factors determined, by the method of Keeney and Raiffa, using a group of 15 college students: 13 in the senior undergraduate year and two graduate students at the Huxley College of Environmental Studies. The students ranged in age from 20 to 45, with a mean age of 28 years; there were 10 males and 5 females in the group. Three of the students characterized themselves as "anti-nuclear"; two, as "pro-nuclear"; the remainder, as neutral.

In consonance with the MUA, single attribute utility functions were determined for the following attributes:

- Radiological and non-radiological worker fatalities
- Radiological and non-radiological general public fatalities
- Radiological and non-radiological transportation fatalities
- Aesthetic impact
- Impact on historical, archaeological and cultural features
- Ecological impact
- Socio-economic impact
- Repository construction and operation cost
- Transportation cost

Three independent single-attribute utility functions were drawn for each attribute, so that each subject participated in three single-attribute utility analyses; the time required for each analysis prohibited having all fifteen subjects do all fourteen analyses. Each subject participated in a different set of analyses. Although three subject seems a small number, it should be remembered that the MUA used a total of five subjects, all of whom participated in all the analyses.

In assessing the single-attribute utilities for the five candidate sites, the rankings developed in the MUA were used, and the utility determined by taking the average of the three utility functions developed for each attribute.

RESULTS AND DISCUSSION

The single-attribute utility functions are shown in Fig. 1-14; the function from the MUA is shown in each figure for comparison. Figures 1, 2, 5 and 6 show the single attribute utility functions for radiological health effects; Fig. 3, 4, 7 and 8 show these for non-radiological health effects. Unlike the utility functions in the MUA, the functions for radiological health effects at the repository are slightly risk averse, and those for transportation include both slightly risk averse

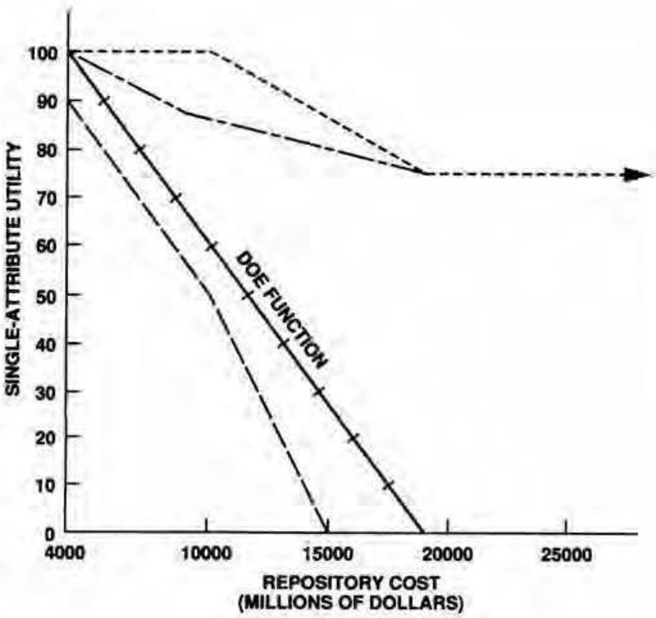

Fig. 13. Utility Function for Repository Cost.

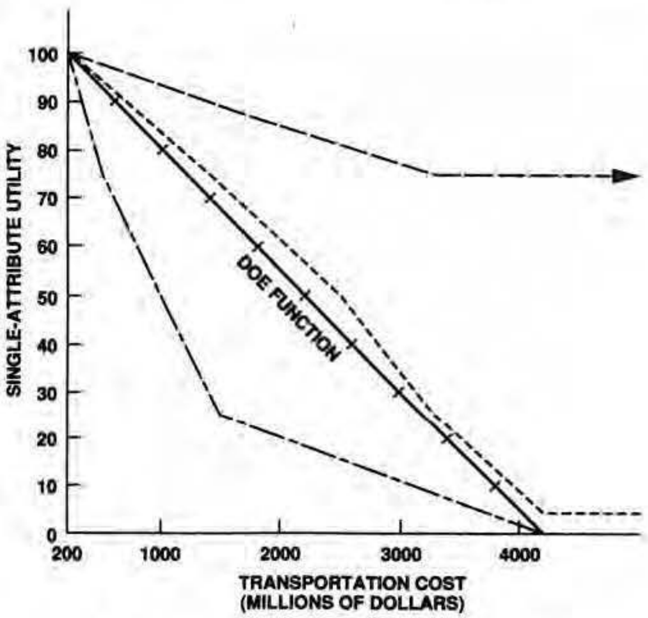

Fig. 14. Utility Function for Transportation Cost.

and slightly risk prone utility functions. Utility functions for non-radiological risk were almost linear.

Utility functions for aesthetic impact, shown in Fig. 9 are less risk averse than those in the MUA, although this may be in part a function of the difference in constructed scales for these two attributes. The same feature is characteristic for archaeological and biological impacts (Fig. 10 and 11), although it is notable that the population used in this study is less tolerant of these impacts on the whole than the sample of the MUA. The utility function for socio-economic impacts (Fig. 12) is more closely aligned to that in the MUA.

Figures 13 and 14 show the utility functions for repository cost and for transportation cost. Although these appear to be risk-neutral, three of them show an unusual feature that might e characterized as "no cost is too high"; indeed, these subjects were unable to imagine a maximum cost. This feature, however, did not affect the utilities of the five candidate sites, because the estimataed costs of all five sites were below 15 billion dollars for construction and four billion for transportation.

Scaling factors were determined using the same population as was used to determine the single-attribute utility functions. The preclosure utility for each site was then determined as a linear function of the single attribute utilities as in Eq. (1).

$U_{comp} = \_k_jU_j, J=1 \text{ to } j=14$ (Eq. 1)

Table II gives the pre-closure utilities for the base case and compares them with those in the MUA.

TABLE II
Reclosure Utilities Of The Candidate Sites

Site	Utility (USDOE)	Rank (USDOE)	Utility	Rank
Davis Canyon	61.3	4	55.8	5
Deaf Smith	66.9	3	70.3	2
Hanford	48.5	5	57.7	4
Richton	70.1	2	71.3	1
Yucca Mtn	75.2	1	68.0	3

The composite utility for each site is then given by Eq. (2)

$U_{comp} = k_{post}U_{post} + k_{pre}U_{pre}$ (Eq. 2)

Figure 15 shows the variation in composite utility for each of the five sites, from the case of $k_{post} = 1.0$ to $k_{pre} = 1.0$, for the base case, and compares the base case results

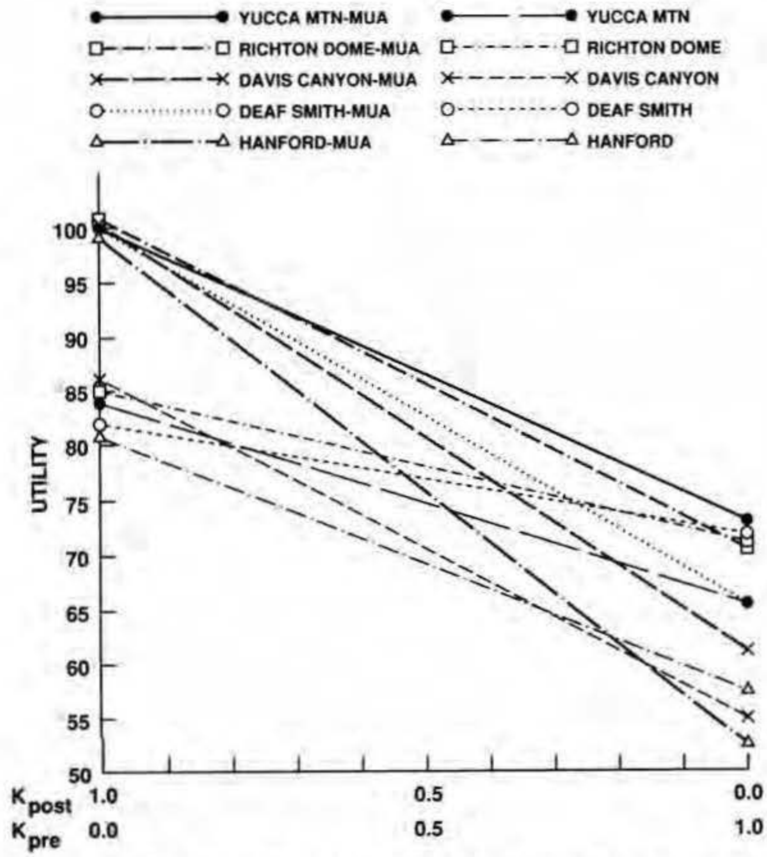

Fig. 15. Comparative Base Case Utilities Varying Pre-Closure and Post-Closure Weights.

for the present study with the base case results in the MUA. Only the base case analysis was completed for this study.

Probably the greatest flaw in the present study is the dependence on DOE rankings of the various sites with respect to the attributes. Since these rankings involve questions of expert judgment, experts representing various points of view (DOE, states, tribes, other agencies) should be involved in the ranking process.

The relative preclosure composite utilities among the five sites do not appear to be particularly sensitive to any single attribute or cluster of attributes. Moreover, these pre-closure utilities are not driven by cost to nearly the extent of the MUA analysis, largely because the "decision makers" for the present study took an entirely different view of cost than was taken by the decision makers of the MUA. In the MUA, the assessment of preclosure multiattribute utility functions was driven by cost of repository construction.

The relative overall utility ranking of the five sites was the same for preclosure as for postclosure conditions, except for Davis Canyon. Davis Canyon ranked highest in postclosure utility but lowest in preclosure utility. This suggests that proximity of the site to the national park drove the preclosure ranking, since such a condition would not affect the postclosure ranking.

Results of our study show the strong dependence of relative composite utilities on decision makers drawing the utility functions. If utility analysis is used as a decision-aiding method in a process to which public input is integral, therefore, a representative group of members of the public or of stakeholders be involved in elucidating the utility functions. This would be the only way to build an accurate picture of relevant public opinion, and to assure that the final decision represents the biases of all the stakeholders. Otherwise, some simpler decision-aiding method, like a modified Delphi analysis, should serve just as well.

It may also be noted that Yucca Mountain ranked third of five in pre-closure utility: it was neither the best nor the worst of the five sites, though the preclosure utility was well above those of Hanford and Davis Canyon.

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