REVIEW OF SITE RECOMMENDATION PROCESS IN DRAFT ENVIRONMENTAL ASSESSMENTS

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ABSTRACT

In December 1984, the U.S. Department of Energy (DOE) published Draft Environmental Assessments (EAs) on nine potentially acceptable nuclear waste repository sites. Five sites in the States of Mississippi, Nevada, Texas, Utah and Washington were proposed in the Draft EAs for nomination under the Nuclear Waste Policy Act as suitable for further detailed study (site characterization). The Nevada, Texas and Washington sites were further proposed for recommendation to the President as preferred for site characterization. This paper reviews the process that DOE used in selecting the three sites proposed for site characterization. The process is consistent with DOE's implementation guidelines for selecting repository sites and proceeds in three steps. First, the sites are ranked in order of preference for each of twenty technical guidelines based on information in the Draft EAs. The second step combines the individual guideline rankings into postclosure and preclosure guideline group rankings, and, finally, into an overall ranking. In the third step, the sensitivity of the choice of the three preferred sites is examined for a range of guideline weightings.

INTRODUCTION

On December 20, 1984, the U.S. Department of Energy (DOE) published nine Draft Environmental Assessments (EAs) for public comment. These Draft EAs contain the data and analyses associated with the nine potentially acceptable sites that DOE is considering for the permanent disposal of spent nuclear fuel and high-level radioactive waste in the Nation's first geologic repository. This paper reviews the analytical procedure that DOE used in determining which three of the nine potentially acceptable sites were to be proposed for further intensive study, called site characterization.

The following nine potentially acceptable sites (alphabetically by State) were identified by DOE in February 1983 in accordance the Nuclear Waste Policy Act of 1982 (NWPA):

Louisiana - Vacherie Dome (salt dome)
Mississippi - Cypress Creek Dome and Richton Dome (salt domes)
Nevada - Yucca Mountain (tuff)
Texas - Deaf Smith County and Swisher County (bedded salt)
Utah - Davis Canyon and Lavender Canyon (bedded salt)
Washington - Hanford (basalt)

The geologic medium of the sites is noted parenthetically. The sites are also identified as being in five geohydrologic settings, the Louisiana and Mississippi sites lying within one such setting and each of the remaining four geographic groupings lying within its own distinct setting.

In accordance with DOE's "General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories" (10 CFR Part 960), a preferred site must be selected from each of the geohydrologic settings. If found suitable for site characterization under the Guidelines, then the preferred sites are eligible for nomination. The NWPA requires that DOE nominate at least five sites as suitable for characterization and recommend not fewer than three of these to the President for approval to begin site characterization. In the Draft EAs the following five sites are proposed for nomination: Richton Dome, Mississippi; Yucca Mountain, Nevada; Deaf Smith County, Texas; Davis Canyon, Utah; and Hanford, Washington.

The NWPA further requires that a comparative evaluation of the nominated sites be performed and the Guidelines then require that a selection of three sites for recommendation to the President for site characterization be developed from the nominated sites. Consistent with these requirements, DOE applied a ranking analysis to the proposed nominated sites to determine the proposed three sites for recommendation. The ranking analysis resulted in Yucca Mountain, Deaf Smith, and Hanford (in no particular order) being proposed in the Draft EAs for recommendation to the President for site characterization.

The Draft EAs contain a common Chapter 7 and an associated appendix which presents the ranking analysis in sufficient detail to allow the reader to reproduce DOE's results. A 90-day public comment period on the Draft EAs ended March 20, 1985. DOE is now considering the comments received, including comments on the site rankings analysis. All comments will receive full and careful consideration in the preparation of the final EAs and the formal nominations and recommendations, which are expected to be made later this year.

DISCUSSION

The process for selecting the three sites proposed for recommendation from the five sites proposed for nomination consists of three steps:

1. Rank the five sites in order of preference for each of the 20 technical guidelines, based on the Draft EAs.

2. Under different methods, combine these individual rankings into rankings for the groups and sets of technical guidelines identified in 10 CFR Part 960, and develop overall rankings of the five sites.

3. Examine the sensitivity of the ranking results for a range of weightings for the guideline groups and sets under the different ranking methods.

Step 1

Table I shows the results of ranking the five sites proposed for nomination for each of the postclosure technical guidelines. The postclosure guidelines establish qualifying and disqualifying conditions effecting the long-term waste isolation capability of a repository. These conditions pertain primarily to a site's geology, hydrology, tectonics, geochemistry, and other features affecting repository system performance for thousands of years.

Table II gives the results of site rankings for the preclosure technical guidelines. The preclosure guidelines establish analogous qualifying and disqualifying conditions for nuclear waste disposal activities prior to repository decommissioning. These conditions concern the protection of the public and repository workers from radiation during repository operations, preventing unacceptable environmental, socioeconomic, and transportation impacts, and ensuring that a repository can be constructed and operated with available technology at reasonable cost.

The rankings in Tables I and II reflect the judgments of technical experts familiar with the information in all of the Draft EAs.

Step 2

Tables III through VI show results of the second step, which combines individual guideline rankings into rankings for guideline sets and groups, and then into the overall ranking. Three simple, recognized quantitative methods, embodying different assumptions, are used to aggregate the individual rankings. They are known as the methods of averaging, pairwise comparison and utility estimation. The essential differences among them are in the ways they arrive at the numerical scores needed for the combinations. The averaging method assigns points to positions in each rank: 5 points for first, 4 for second, etc., and adds scores to produce combined rankings. The pairwise comparison method examines every possible pair of sites, determines which one is better for groups and sets of technical guidelines, and subtracts "losses" from "wins" to determine scores for each site. The utility estimation method, which requires the most detailed information about each site, assigns a numerical score between 1 and 10 to each site for each technical guideline, and then combines scores in essentially the same way as the other methods. Table X shows these numerical ratings.

Tables III and IV show results of the three aggregation methods, for the postclosure set and for each of the three preclosure groups, respectively, where weighting is not involved. Tables V and VI show results where the three preclosure groups are weighted and combined to derive a ranking for the preclosure set, which is then combined with the postclosure set to produce the overall result. The particular weighting assignment used, called the reference case, assigns the technical guideline groups and sets as close to equal weight as possible, consistent with the implementation guidelines in 10 CFR Part 960. Those guidelines specify only that the set of postclosure guidelines must have greater weight than the set of preclosure guidelines, and that the three groups of preclosure guidelines (radiological safety; environment, socioeconomics and transportation; ease and cost of siting, construction, operation and closure) must be considered in decreasing order of importance. They do not specify the precise weights to use. Thus, a weighting relationship which assigns the postclosure guidelines only slightly more weight than the preclosure guidelines is as consistent with a strict interpretation of the requirements as one which assigns the postclosure guidelines ten times the weight of the preclosure guidelines. Similarly, assigning almost equal weight to the three groups of preclosure guidelines is as allowable as assigning the first group on radiological safety vastly greater weight than either of the other two groups. For the reference case, therefore, the postclosure-preclosure weights were chosen to be in the numerical ratio 51:49, and the weights of the three preclosure groups were chosen to be in the ratio 35:33:32.

Step 3

This flexibility in assigning weights to the sets and groups of technical guidelines has been examined closely to determine the sensitivity of the final results to variations in the weights. The most important conclusion of the analysis is that as long as the set of postclosure guidelines is constrained to be no more than about four times as important as the set of preclosure guidelines, or the first preclosure group is similarly constrained to be no more than about four times as important as either of the other two groups, no allocation of weights within these bounds will change the result that the Deaf Smith, Hanford and Yucca Mountain sites are preferred (in no particular order) for recommendation. This conclusion is valid for all three of the aggregation methods.

The analysis of the sensitivity of site selection to changes in the relative weights of the guideline sets and groups consists in comparing the rankings for the reference case with "bounding" cases as well as a representative sampling of "intermediate" cases. The bounds are determined by the guidelines, as indicated previously. For the postclosure-preclosure weightings, they permit weights in the range where the postclosure and preclosure sets of guidelines have almost equal weight to where the postclosure guidelines are vastly more important; for example, where the postclosure-preclosure weighting ratio varies from approximately 51:49 to approximately 90:10. The ratios 51:49, 60:40, 75:25 and 90:10 were examined systematically, and others were studied as well. Similarly, within the preclosure set, bounds extend from weighting ratios of 33:33:33 through 50:50:0 to 100:0:0 for the three subordinate preclosure groups. In addition to these bounds, intermediate cases explicitly studied included the ratios 35:33:32, 37:33:30, 44:33:23, 50:33:17, and 55:33:12.

TABLE I

Ranking of Sites for Each Technical Guideline in the Postclosure Set

Geohydrology	Dissolution
1. Davis Canyon, Deaf Smith, Richton 2. Yucca Mountain 3. Hanford	1. Hanford, Yucca Mountain, 2. Davis Canyon, Deaf Smith 3. Richton
Geochemistry	**Tectonics**
1. Hanford 2. Davis Canyon, Deaf Smith, Yucca Mountain 3. Richton	1. Deaf Smith 2. Richton 3. Davis Canyon 4. Hanford 5. Yucca Mountain
Rock Characteristics	**Natural Resources**
1. Davis Canyon, Richton 2. Deaf Smith 3. Hanford, Yucca Mountain	1. Yucca Mountain 2. Hanford 3. Davis Canyon Deaf Smith 4. Richton
Climatic Changes	**Site Ownership and Control**
All sites equal	All sites equal
Erosion	
All sites equal	

TABLE II

Rankings of Sites for Each Technical Guideline in the Preclosure Set

GROUP 1. RADIOLOGICAL SAFETY

Population Density	Site Ownership and Control	Meterology	Offsite Installations and Operations
1. Yucca Mt. 2. Davis Canyon 3. Hanford, Deaf Smith 4. Richton	1. Hanford 2. Deaf Smith, Richton 3. Yucca Mt. 4. Davis Canyon	1. Yucca Mt. 2. Hanford 3. Deaf Smith, Richton 4. Davis Canyon	1. Davis Canyon 2. Richton 3. Deaf Smith 4. Hanford 5. Yucca Mt.

GROUP 2. ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION

Environmental Quality	Socioeconomic Impacts	Transportation
1. Hanford, Yucca Mt. 2. Deaf Smith 3. Richton 4. Davis Canyon	1. Hanford 2. Yucca Mt. 3. Richton 4. Deaf Smith 5. Davis Canyon	1. Deaf Smith, Richton 2. Yucca Mt., Hanford 3. Davis Canyon

GROUP 3. EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE

Surface Characteristics	Rock Characteristics	Hydrology	Tectonics
1. Deaf Smith, Hanford, Yucca Mt, 2. Richton 3. Davis Canyon	1. Yucca Mt. 2. Davis Canyon, Richton 3. Deaf Smith 4. Hanford	1. Yucca Mt. 2. Davis Canyon, Deaf Smith, Hanford, Richton	1. Deaf Smith, Richton 2. Davis Canyon 3. Hanford 4. Yucca Mt.

TABLE III

Rankings of Sites for the Set of Postclosure Guidelines

Averaging	Pairwise Comparison	Utility Estimation
1. Deaf Smith	1. Davis Canyon, Deaf Smith,	1. Yucca Mt.
2. Davis Canyon	2. Hanford	2. Deaf Smith
3. Hanford	3. Richton, Yucca Mt.	3. Davis Canyon, Hanford
4. Yucca Mt.		4. Richton
5. Richton		

TABLE IV

Rankings of Sites for Preclosure Groups of Guidelines

GROUP 1. RADIOLOGICAL SAFETY

Averaging	Pairwise Comparison	Utility Estimation
1. Hanford	1. Hanford	1. Hanford
2. Yucca Mt.	2. Yucca Mt.	2. Yucca Mt., Deaf Smith
3. Deaf Smith	3. Deaf Smith, Davis Canyon, Richton	3. Davis Canyon
4. Davis Canyon, Richton		4. Richton

GROUP 2. ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION

1. Hanford	1. Hanford	1. Hanford
2. Yucca Mt.	2. Yucca Mt.	2. Yucca Mt., Deaf Smith, Richton
3. Deaf Smith, Richton	3. Richton, Deaf Smith	3. Davis Canyon
4. Davis Canyon	4. Davis Canyon	4. Deaf Smith

GROUP 3. EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE

1. Yucca Mt.	1. Yucca Mt.	1. Yucca Mt.
2. Deaf Smith	2. Richton, Deaf Smith	2. Richton, Deaf Smith
3. Richton	3. Davis Canyon	3. Davis Canyon
4. Davis Canyon	4. Hanford	4. Hanford
5. Hanford		

TABLE V

Rankings of Sites for the Preclosure Set of Guidelines for Reference Weighting of Subordinate Groups

Averaging	Pairwise Comparison	Utility Estimation
1. Yucca Mt.	1. Hanford	1. Yucca Mt.
2. Deaf Smith	2. Yucca Mt.	2. Deaf Smith, Hanford
3. Hanford	3. Deaf Smith	3. Richton
4. Richton	4. Richton	4. Davis Canyon
5. Davis Canyon	5. Davis Canyon	

TABLE VI

Overall Rankings of Sites for Reference Postclosure-Preclosure Weighting and Reference Weightings of Preclosure Groups

Averaging	Pairwise Comparison	Utility Estimation
1. Yucca Mt.	1. Hanford	1. Yucca Mt.
2. Hanford	2. Yucca Mt.	2. Hanford
3. Deaf Smith	3. Deaf Smith, Richton	3. Deaf Smith
4. Richton	4. Davis Canyon	4. Richton
5. Davis Canyon		5. Davis Canyon

These various weighting allocations must be used in combining the scores for the three preclosure groups to produce a score for the whole preclosure set, and in combining the score for the postclosure set with the score for the preclosure set to obtain an overall score. The procedure for doing this for the averaging and utility estimation methods involves identifying the proper weight for each technical guideline condition, then multiplying the score for each site by that weight, and, finally, adding the scores for each site over all twenty guidelines. For the pairwise comparison method, it requires including the weight of each guideline condition when determining the wins and losses, much as in the voting of shares of stock in a corporation. For all the methods, inspection of the aggregated scores leads immediately to the resulting ranks.

Tables VII and VIII show representative results of the analysis. They give rankings and numerical scores found for preclosure weighting ratios of 35:33:32, 44:33:23, 55:33:12, and 50:50:0, for all four of the postclosure-preclosure weighting ratios listed above, for all three aggregation methods. In almost all cases, the Deaf Smith, Hanford and Yucca Mountain sites are in the top three ranks and the Davis Canyon and Richton sites are in the bottom two ranks. Table VIII shows that when extreme weight is given to the postclosure set (90:10), the averaging and pairwise comparison methods rank the Davis Canyon site third and the Yucca Mountain site fourth. This is a reflection of the fact that Davis Canyon ranks higher than Yucca Mountain for these two methods for the postclosure guidelines, and the fact that the preclosure guidelines, where Yucca Mountain is stronger, are given very little weight. The general trend observed is that as the weighting allocation moves away from the situation where all the guideline sets and groups are weighted nearly equally, any special advantages that a site may tend to become more significant, or its disadvantages less so, depending on what direction the weighting takes.

To further examine the possibility that some other assignment of weights might produce results different from these specific cases, a computer-based searching procedure known as direct-search minimization was invoked. The objective of the search was to find a set of weights that would change the overall scores in such a way that the lowest score computed for any of the sites that initially were in the top three ranks became lower than the highest score computed for either of the sites that initially were in the bottom two. Searches were started out from each case where Deaf Smith, Hanford and Yucca Mountain were in the top three ranks, and were allowed to proceed until this ranking was changed, or until it became clear that it would not change. All the searches were constrained to keep the weights within the bounds stipulated by the guidelines.

The computer runs led to no new cases with different overall rankings. However, they did help discover the precise postclosure-preclosure weight ratios where the averaging and pairwise comparison methods changed their preferred top three sites. In addition, it was found that the preclosure 33:33:33 and 100:0:0 bounding cases came nearer to closing the gap between the top three and the bottom two sites than any "reachable" alternative. Whereas, the 50:50:0 case did not; it became transformed into the 33:33:33 case. The computer runs also revealed that for a number of intermediate preclosure cases, ratios near *33:33:33* often narrowed the gap between the top three and the bottom two sites. Table IX shows some of these results.

The question of the sensitivity of the overall rankings to variations in the numerical ratings of the utility estimation method, shown in Table X, may be examined as follows. For the reference case, where the guideline sets and groups are assigned weights that are close to equal, the weight of each guideline ranges from a low of 3.9 (0.32x49/4) for guidelines in the third preclosure group to 5.7 (51/9) for guidelines in the postclosure set, with an average of 5. As a result, a variation of one point in the rating of any one site for any one guideline will change that site's overall score by no more than 5.7 points. Since the difference between the lowest score for the top three sites and the highest score for the top two sites is 47 points, no change in rankings will occur unless the lowest ranked site in the top three (Deaf Smith) or the highest ranked site in the bottom two (Richton) can have its score changed by at least this amount. Thus, the ratings for Deaf Smith or Richton would have to be changed by 1 point for approximately 9 of the 20 guideline conditions, or by 2 points on 5 of them, etc., or by a combination of 1-point changes for some and 2- or more point changes for others, if a "crossover" were to be produced.

Similar reasoning applies in all the intermediate cases, because they have gaps of comparable magnitude to the reference case. Because the guidelines are not fully independent and there are a number of instances where scores are tied, the analysis suggests that a substantial fraction of the ratings would need to be changed to modify the final choice of the three preferred sites.

CONCLUSIONS

It is important to emphasize at least two aspects of this work. The first is that the final choice of three recommended sites appears to be significantly insensitive to reasonable variations in weights and scores. The second is that all these results are tentative. They will be re-examined and re-worked as needed in light of the public comments.

TABLE IX

Computer Searches

START post	START pre	L/H 3/2		FINISH post	FINISH pre	L/H 3/2
		Utility estimation				
90	35:33:32	H/DC		90	34:33:33	H/DC
75	35:33:32	H/DC		83	72:14:14	H/DC
51	35:33:32	DS/R		51	34:33:33	H/R
90	44:33:23	Y/DC		90	34:33:33	H/DC
75	44:33:23	H/DC		77.	100:0:0	DS/DC
51	44:33:23	DS/R		51	34:33:33	DS/R
90	55:33:12	H/DC		90	42:29:29	H/DC
60	55:33:12	DS/R		54	43:29:28	DS/R
51	55:33:12	DS/R		51	42:29:29	DS/R
90	50:50:0	H/DC		90	36:32:32	H/DC
60	50:50:0	DS/R		53	34:33:33	H/R
51	50:50:0	DS/R		51	36:32:32	DS/R
		Pairwise comparison				
90	35:33:32	DC/Y		90	---	
85	35:33:32	Y/DC	—X	87	50:37:13	DC/Y
75	35:33:32	Y/DC		75	35:33:32	Y/DC
90	44:33:23	DC/Y		90	---	
85	44:33:23	Y/DC	—X	87	50:37:13	DC/Y
60	44:33:23	DS/R		60	44:33:23	DS/R
90	55:33:12	DC/Y		90	---	
85	55:33:12	Y/DC	—X	87	62:31:1	DC/YC
75	55:33:12	Y/DC		75	55:33:12	Y/DC
90	50:50:0	DC/Y		90	---	
75	50:50:0	Y/DC		75	50:50:0	Y/DC
60	50:50:0	Y.DS/R	—T	54	44:44:12	DS/R
		Averaging				
90	35:33:32	DC/Y		90	---	
75	35:33:32	Y/DC	—X	83	66:31:3	DC/Y
60	35:33:32	H/R		60	34:33:33	H/R
90	44:33:23	H/Y		90	---	
75	44:33:23	Y/DC	—X	75	83:14:3	DC/Y
60	44:33:23	Y/R		66	57:43:0	Y/R
90	55:33:12	H/Y		90	---	
75	55:33:12	Y/DC	—X	75	80:12:8	DC/Y
60	55:33:12	Y/R		61	62:38:0	Y/R
90	50:50:0	DC/Y		90	---	
75	50:50:0	Y/DC	—X	75	80:15:5	DC/Y
60	50:50:0	Y/R		60	50:50:0	Y/R

TABLE X

Numerical Rating of Sites for Each Technical Guideline

	1	2	3	4	5	6	7	8	9	10
POSTCLOSURE										
Geohydrology						H		Y	OS.R,DC	
Geochemistry							R	Y.DC.OS	H	
Rock Characteristics							Y,H	OS	DC.R	
Climatic changes									All	
Erosion									All	
Dissolution					R		DC.OS			Y,H
Tectonics						Y	H	DC	R	OS
Natural Resources				R		DC.OS		H		Y
Site ownership and control										All
PRECLOSURE										
Population Density			R				H.OS	DC		Y
Site Ownership					DC	Y		R,OS		H
Meteorology						DC	OS.R		H	Y
Offsite installations			Y		H		OS	R	DC	
Environmental quality			DC		R		OS		H,Y	
Socioeconomic impacts				DC	OS	R		Y	H	
Transportation		DC				Y.H		R.OS		
Surface Characteristics				DC			R	H,Y,OS		
Rock Characteristics			H		OS	R,DC		Y		
Hydrology						Others				
Tectonics				Y	H		DC		R,OS	

H=Hanford, Y=Yucca Mountain, DC=Davis Canyon, OS=Deaf Smith, R=Richton