
Nuclear Waste Policy Act
(Section 112)



***Recommendation By The
Secretary of Energy of Candidate
Sites For Site Characterization For
The First Radioactive-Waste
Repository***

May 1986

***U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585***

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**RECOMMENDATION BY THE SECRETARY OF ENERGY
OF CANDIDATE SITES FOR SITE CHARACTERIZATION
FOR THE FIRST RADIOACTIVE-WASTE REPOSITORY**

May 1986

BACKGROUND AND SUMMARY

The Nuclear Waste Policy Act of 1982 (the Act), established a step-by-step process for the siting of the nation's first repository for high-level radioactive waste and spent fuel. The Act gave the Department of Energy (DOE) the primary responsibility for conducting this siting process.

The first step in the process laid out in the Act was the development by the DOE, with the concurrence of the Nuclear Regulatory Commission (NRC), of general guidelines to be used by the Secretary of the DOE (the Secretary) in considering candidate sites for recommendation for the location of repositories. These guidelines were issued by the DOE after public review and comment on November 30, 1984.

The second step is the nomination by the Secretary of at least five sites he determines suitable for site characterization for selection of the first repository site. Each nomination is required to be accompanied by an environmental assessment to include, among other things, evaluations of the suitability of the nominated sites under the guidelines. Draft environmental assessments informing the affected States and Indian tribes of the proposed nominations were issued in December 1984. After consideration of the comments received on the draft environmental assessments, the Secretary has nominated the Richton Dome, Mississippi, the Yucca Mountain, Nevada, the Deaf Smith County, Texas, the Davis Canyon, Utah and the Hanford, Washington sites as suitable for site characterization and has caused to be published final environmental assessments for each nominated site.

Both the guidelines and the environmental assessments were finalized reflecting comments received on their respective drafts, including those of the States, Indian tribes, other Federal agencies, and the public.

Subsequent to the nominations, as a third step, the Secretary is to recommend three of the nominated sites to the President for approval for characterization. This report provides that recommendation decision.

The recommendation decision is supported by extensive data, analyses, evaluations, and documentation. The guidelines establish the basic process and criteria under which the sites are evaluated. The environmental assessments provide analyses and evaluations of available data relevant to the suitability of the nominated sites. A subsequent analysis entitled, Multiattribute Utility Analysis of Sites Nominated for Characterization for the First Radioactive Waste Repository--A Decision-Aiding Methodology (DOE/RW-0074), was developed and finalized by the DOE to aid in determining the preferred ranking of the five nominated sites. The suitability and

application of this methodology was reviewed and commented on by the National Academy of Sciences. This decision-aiding methodology was a refinement of one of several methods proposed in the draft environmental assessments in 1984. It utilized the data and analyses in the environmental assessments in a decision process that allowed disaggregation of a complex set of objectives into component parts for evaluation and then reaggregation to determine both a composite ranking of the nominated sites and additional significant information relevant to determining an initial order of preference.

In addition, the DOE has considered the provisions in the siting guidelines for diversity of geohydrologic settings and diversity of rock types in arriving at a final order of preference. Based on these considerations, the Secretary has determined that the set of three sites for recommendation as candidate sites for characterization consists of sites at Yucca Mountain, Nevada; Deaf Smith County, Texas; and Hanford, Washington. In addition, pursuant to the requirements of Section 114(f) of the Act, the Secretary has made a preliminary determination that these three sites are suitable for development as geologic repositories consistent with the siting guidelines.

METHODOLOGY AND APPROACH

Section 112(b) of the Act requires that, following issuance of the siting guidelines and consultation with the Governors of the affected States, the Secretary shall nominate at least five sites that he determines are suitable for site characterization for selection of the first repository site. Further, the Act requires in Section 112(b)(1)(E) that each nomination of a site shall be accompanied by an environmental assessment. Accordingly, the Secretary has nominated the Davis Canyon site, the Deaf Smith County site, the Hanford site, the Richton Dome site, and the Yucca Mountain site as suitable for site characterization and has caused to be published final environmental assessments, consistent with the requirements of the Act, for each nominated site.

Subsequent to the nomination, the Act requires that the Secretary shall recommend in writing to the President three of the nominated sites for characterization as candidate sites. The process used by the DOE to recommend sites for characterization is set forth in Section 960.3-2-3 of the DOE's siting guidelines (10 CFR Part 960). That section states that the recommendation decision shall be based on the available geophysical, geologic, geochemical, and hydrologic data; other information; and associated evaluations and findings reported in the environmental assessments accompanying the site nominations. On the basis of this evidence, the sites nominated as suitable for characterization shall be considered as to their initial order of preference as candidate sites for characterization. Subsequently, the siting provisions specifying diversity of geohydrologic settings and diversity of rock types shall be considered in determining a final order of preference for the characterization of such sites.

The objective of this process is to ensure that "the sites recommended as candidate sites for characterization shall offer, on balance, the most advantageous combination of characteristics and conditions for successful

development of repositories at such sites." In the recommendation decision, the DOE is required to utilize geologic considerations as the primary factor in evaluating sites for geologic repositories. The Act states that the siting guidelines "shall specify detailed geologic considerations that shall be primary criteria for the selection of sites in various geologic media." The siting guidelines, in turn, specify that site evaluations "shall place primary significance on the postclosure guidelines and secondary significance on the preclosure guidelines, with each set of guidelines considered collectively for such purposes."

The DOE has developed and applied a formal, multiattribute, utility-estimation, decision-aiding methodology to aid in determining preferred sites for recommendation for characterization (Multiattribute Utility Analysis of Sites Nominated for Characterization for the First Radioactive-Waste Repository--A Decision-Aiding Methodology, DOE/RW-0074). The methodology allows disaggregation of a complex set of objectives into component parts for evaluation, and then reaggregation in a logical and appropriate manner to determine both a composite ranking of the sites and additional significant information relevant to determining an initial order of preference. As such, the decision-aiding methodology is well-suited to the first step of the decision process wherein the separate postclosure and preclosure objectives are considered individually and then collectively. The methodology is constructed to elucidate the uncertainties inherent at this stage of the siting process, and the methodology is explicit in identifying the relative advantages and disadvantages of each site and the factors (e.g., technical data, professional judgments, value judgments, policy decisions, and models) that critically affect the relative desirability of the sites. The methodology includes substantive sensitivity analyses which allow for a range of viewpoints and evaluates alternative combinations of the factors that describe discrete aspects of site performance. The implications of these sensitivity analyses can be easily identified, examined, and factored into the basis for the site-recommendation decision.

Like most formal methods, however, the decision-aiding methodology is capable of providing only a partial and approximate accounting of the many factors important to the site-recommendation decision. Furthermore, the decision-aiding methodology does not apply the diversity guidelines required to determine a final order of preference among the sites and is not structured for a portfolio-selection decision like the site-recommendation decision. The application of the methodology does, however, provide valuable insights contributing to the site-recommendation decision.

The DOE identified two postclosure objectives related to the isolation of spent fuel and high-level waste from the accessible environment and prevention of adverse impacts to the health and safety of the public after repository closure. These objectives are:

1. Minimize the adverse health effects attributable to the repository during the first 10,000 years after repository closure.
2. Minimize the adverse health effects attributable to the repository during the period 10,000 to 100,000 years after repository closure.

For both objectives, the limits on cumulative releases of radionuclides to the accessible environment (as defined by the Environmental Protection Agency (EPA) in 40 CFR Part 191) were used as a surrogate performance measure for adverse health and safety impacts. Performance measure scales, based on various multiples of the EPA limits, were constructed. In addition, the DOE developed sets of site characteristics for which the various multiples of the EPA limits on the performance measure scales were judged to be reasonable. Consistent with the EPA standard and NRC regulation, the DOE applied the EPA release limits at the edge of the accessible environment.

The National Academy of Sciences Board on Radioactive Waste Management recommended that the DOE evaluate the differences among the sites with respect to pathways from the accessible environment to the biosphere. The DOE reviewed the estimates of cumulative releases to the accessible environment and ground-water travel times in the environmental assessments and observed that radionuclides transported through the ground-water systems should not discharge to the ground surface or surface-water bodies during the next 10,000 to 100,000 years. Instead, likely pathways to the biosphere would consist of wells or borings drilled for water or mineral exploration. The DOE has evaluated both of these pathways in the environmental assessments and the decision-aiding methodology.

In the application of the methodology, the DOE assessed the utility of cumulative releases during the first 10,000 years following repository closure and made a judgment that a site with releases that are 10,000 times lower than the EPA limit (score of 10 on the performance measure scale and utility of 99.99) has little practical advantage over a site with releases that are 100 times higher (score of 6 on the performance measure scale and utility of 99.00). The DOE made a similar judgment for the utility of cumulative releases during the period of 10,000 to 100,000 years following repository closure. In both cases, the judgment is reasonable because the releases would be so small as to be insignificant in comparison with both the EPA standard and natural background radiation and because further increases in score above 6 correspond to very small reductions in the magnitude of releases.

For both time periods, the base-case scores assigned for all sites for all scenarios were 6 or higher. The very low cumulative releases (and high scores) are consistent with numerous studies, expert opinion, and peer review reported in the literature over the past decade. Combining the base-case scores with the base-case probabilities for all scenarios results in expected postclosure utilities for the sites ranging between 99.76 and 99.99 (on a scale of 100) - clearly indicating that all five sites are expected to perform exceedingly well and that there is little practical advantage of one site over another site with respect to postclosure performance. This does not mean that the sites are equal; to the contrary, the scores indicate there may be an order of magnitude difference between the sites in releases to the accessible environment over 10,000 years. However, this difference in releases is not considered to be significant since even the site with the highest releases, the Hanford site, is estimated to be nearly three orders of magnitude lower than the EPA limits. In addition, the improvement between the sites with the highest and lowest releases corresponds to a very small change, i.e., from two one-thousandths (0.002) of the EPA limit to one ten-thousandth (0.0001) of the EPA limit. The results of the preliminary performance assessments in the

environmental assessments tend to confirm both the low estimated releases and the slight differences in estimated releases among the sites.

The DOE identified four preclosure objectives: minimizing adverse impacts on health and safety before closure, minimizing adverse environmental impacts, minimizing adverse socioeconomic impacts, and minimizing economic costs. For these objectives, the DOE developed eight performance measures related to health and safety of the public and workers, three performance measures related to environmental impacts, one performance measure related to socioeconomic impacts, and two performance measures related to economic costs.

Base-case impacts were estimated for each site for each performance measure. The individual preclosure impacts were aggregated to determine a best estimate of impacts and to perform sensitivity analyses across the range of estimated impacts. In this manner, the impacts for each of the four preclosure objectives were determined and the aggregate impacts for the total preclosure analysis were derived. As in the case of the postclosure evaluation, the application of the methodology has provided the DOE with valuable insights related to the site-recommendation decision.

For the eight performance measures related to radiological and non-radiological health and safety of the public and workers, the aggregation of impacts shows that, as a best estimate, the Richton Dome site would cause the least impacts, followed by the Deaf Smith County site, the Davis Canyon site, the Yucca Mountain site, and the Hanford site. For the three environmental and one socioeconomic performance measures, the aggregation of impacts shows that, as a best estimate, the Hanford site would cause the least impacts, followed by the Yucca Mountain site, the Deaf Smith County site, the Richton Dome site, and the Davis Canyon site. For the two performance measures related to repository and transportation costs, the aggregation of impacts shows that, as a best estimate, the Yucca Mountain site would cause the least impacts, followed by the Richton Dome site, the Deaf Smith County site, the Davis Canyon site, and the Hanford site. If these three groupings are then aggregated to determine the best estimate of combined, base-case impacts for all fourteen of the preclosure performance measures, the Yucca Mountain site would cause the least impacts, followed by the Richton Dome site, the Deaf Smith County site, the Davis Canyon site, and the Hanford site.

Various combinations of preclosure performance measures provide significant insight into the factors that most influence the relative desirability of the sites. Alternative combinations of preclosure performance measures yield different preclosure rankings of the sites. For example, if the two preclosure performance measures on repository and transportation costs are not considered and the base-case impacts of the other twelve preclosure performance measures are aggregated, the Hanford site would cause the least impacts, followed by the Yucca Mountain site, the Deaf Smith County site, the Richton Dome site, and the Davis Canyon site. This alternative combination demonstrates that the combined base-case impacts for all fourteen of the preclosure performance measures are most strongly influenced by the estimated repository and transportation costs—factors that are the least important of all guideline subgroups in the siting guidelines.

The sensitivity analyses in the preclosure evaluation indicate that the estimated repository and transportation costs dominate the site rankings determined by aggregating the fourteen preclosure performance measures over the range of high, base-case, and low scores. Although it is clear from the Act and the siting guidelines that costs are a factor in site selection, it is equally clear that the postclosure performance of the sites and other technical factors should take precedence over costs. This is especially appropriate given the preliminary nature of the repository cost estimates available at this time. The National Academy of Sciences Board on Radioactive Waste Management appears to confirm this viewpoint in their independent review of the decision-aiding methodology wherein they state: "This recognition of the heavy dependence on cost reinforces the Board's judgment that the principal usefulness of the multiattribute utility method is to illuminate the factors involved in a decision, rather than to make the decision itself."

DIVERSITY PROVISIONS

The siting guidelines specify that diversity of geohydrologic settings and diversity of rock types shall be considered in determining a final order of preference for the characterization of candidate sites. The five sites nominated by the Secretary as suitable for site characterization provide the maximum diversity in geohydrologic settings because each site is in a distinct geohydrologic setting. Any combination of three recommended sites will, therefore, provide the maximum diversity in geohydrologic settings.

The provision on diversity of rock types provides both insurance against deficiencies or failure common to all sites of a particular rock type and an opportunity to evaluate the siting, design, licensing, construction, and operation of a geologic repository for diverse rock types. The provision on diversity of rock types offers an opportunity for the DOE to consider, during the site selection process, the advantages of alternatives in such areas as repository design, waste package design, and options for retrievability as well as alternative performance allocations and performance assessment capabilities for sites in different rock types.

The Act requires that the Secretary "consider the various geologic media in which sites for repositories may be located and, to the extent practicable, recommend sites in different geologic media." The siting guidelines state that "to the extent practicable...sites recommended as candidate sites for characterization shall have different types of host rock."

ORDER OF PREFERENCE AND RECOMMENDATION

Aggregating the postclosure and preclosure analyses in the methodology to determine composite utilities for the sites provides a composite ranking of the Yucca Mountain site, the Richton Dome site, the Deaf Smith County site, the Davis Canyon site, and the Hanford site. A most useful characteristic of this methodology, as illuminated above, is the ability to understand how individual factors and combination of factors contribute to the composite

ranking. In this case it is clear that the preclosure repository and transportation costs, primarily because of the very small differences among sites in postclosure performance, control the composite ranking provided by the decision-aiding methodology. While such costs are relevant in the process, the objective of this recommendation decision is to select a suite of three sites for characterization, i.e., extensive study, that offer, on balance, the most advantageous combination of characteristics and conditions for the successful development of repositories at such sites. Although there may be a point in the siting process where such costs might appropriately be a significant factor, such as in a decision between three fully characterized and potentially licensable sites, the cost estimates are very preliminary at this time and they should not unduly influence the outcome of the decision made here. The guidelines note that such costs should be among the factors given the least importance among preclosure considerations.

Thus, in deciding on an initial order of preference, the decision-aiding methodology has provided significant insights on both the relative desirability of the sites and identification of the factors that most influence the desirability. In the postclosure evaluation, it is significant that all sites are expected to perform exceptionally well in isolating the high-level wastes and spent fuel from the accessible environment. Although there are measurable differences between the sites, these differences are small and not significant with respect to the ability to meet the EPA standard. Thus, the postclosure evaluation is most important, not as a discriminator, but as evidence that all sites are quite attractive with regard to postclosure performance.

In preclosure, all sites are also expected to perform well. However, in the preclosure evaluation there are more performance objectives, which provide a greater variety of performance measures and a greater complexity in aggregating them into a composite score. Accordingly, it is appropriate to look at various combinations of performance measures to develop insight into those factors that cause discrimination among the sites. Several insights are readily apparent. As mentioned in the composite aggregation of all the preclosure performance measures, repository and transportation costs dominate the results, even though the siting guidelines place costs among the least important category of consideration. Aggregating all preclosure performance measures other than repository and transportation costs markedly alters the rank ordering of the sites.

Taking this information into account, the Yucca Mountain site scores well and is attractive as a candidate site. It is expected to perform very well in postclosure and scores best in preclosure when all performance measures are aggregated. In almost every alternative combination of preclosure performance measures considered, the Yucca Mountain site scores at or near the top. It is also the only tuff site and therefore preserves the option to characterize the maximum number of rock types.

The Hanford site also scores well in postclosure. Though it is highest in expected releases to the environment, the estimated releases over 10,000 years represent only two-tenths of one percent (0.002) of the EPA standard. Its relative standing among the sites in preclosure depends markedly on the alternative combinations of performance measures considered. While it is

ranked fifth when all of the preclosure objectives are aggregated, it is clear that this ranking is driven by the significantly higher expected costs. In fact, if all preclosure objectives except repository and transportation costs are aggregated, Hanford becomes the most desirable site, a telling factor given the low relative importance assigned by the siting guidelines to costs.

These estimated costs are sharply reduced for all sites, especially the Hanford site, if the cost estimates are based on the time value of money, rather than constant 1985 dollars, for activities that will occur decades later, e.g., backfilling, decommissioning and closure. Likewise, the cost differences between the Hanford site and the salt sites would be offset by the estimated differences in the cost of retrieval, in the unlikely event that retrieval would be necessary. Accordingly, the higher costs at the Hanford site are not so firm as to be the dominant factor in the site-recommendation decision. In addition, the selection of a site with higher costs for development as the first geologic repository would be entertained only if the postclosure performance of the sites and other technical factors evaluated during site characterization show the higher costs to be warranted.

The Hanford site also scores first in minimizing impacts on the environment, minimizing impacts on socioeconomic conditions, and minimizing site impacts. While expected repository and transportation costs are significantly higher than for the other four sites, and the transportation impacts, primarily non-radiological, away from the site are higher than for the other four sites, the decision being made now is to choose a slate of three sites to characterize. The costs of characterization of all the sites, including Hanford, are quite comparable. Since Hanford is the only basalt site, it too preserves the option to maximize the number of rock types characterized.

This leaves consideration of the three salt sites. First, it is clear that all three sites are expected to perform exceptionally well in postclosure. In fact, the analyses show them performing exceedingly well, even in the event that highly unlikely disruptive events occur. However, the preclosure evaluation shows clearly that the Davis Canyon site is the least-preferred salt site for the overall aggregation of preclosure performance measures and any of the other combinations considered.

Evaluating the relative performance of the Deaf Smith County site and the Richton Dome site is more difficult because their performance is comparable. For example, aggregating all of the preclosure performance measures shows a slight preference for the Richton Dome site over the Deaf Smith County site. Aggregating the same performance measures except for repository and transportation costs, however, shows a slight preference for the Deaf Smith County site over the Richton Dome site. Likewise, aggregating the preclosure health and safety impacts both during transportation and at the repository shows a slight preference for the Richton Dome site over the Deaf Smith County site, but, aggregating only the impacts to the public and workers at or near the repository site shows a slight preference for the Deaf Smith County site over the Richton Dome site. In addition, aggregating the performance measures related to environment and socioeconomics shows a slight preference for the Deaf Smith County site over the Richton Dome site. In fact, the various combinations of preclosure performance measures considered in this analysis

show that the Deaf Smith County site predominantly ranks in the top three sites in order of preference, whereas the Richton Dome site ranges from first to fourth in order of preference for the same combinations of preclosure performance measures. Indeed, the Richton Dome site ranks fourth in several of the preclosure performance measure aggregations. Taking all of the information presented above and in the application of the decision-aiding methodology into account, with particular consideration of the uncertainty and timing of costs, leads to an initial order of preference in which the Yucca Mountain, Nevada, Deaf Smith County, Texas, and Hanford, Washington sites are the three preferred sites for characterization.

This initial order of preference provides the maximum diversity of geohydrologic settings and rock types. Consequently, following consideration of such diversity, it has been determined that the Yucca Mountain, Deaf Smith County, and Hanford sites are the three sites which constitute the final order of preference. Furthermore, based on the above discussion, it has been determined that the Yucca Mountain, Nevada, Deaf Smith County, Texas, and Hanford, Washington sites offer, on balance, the most advantageous combination of characteristics and conditions for successful development of repositories at such sites.

PRELIMINARY DETERMINATION OF SUITABILITY

The three recommended sites, Yucca Mountain, Nevada; Deaf Smith County, Texas; and Hanford, Washington, were found by the Secretary, at the time they were nominated, to be suitable for site characterization. Upon further consideration of the evaluations of these sites in the environmental assessments, including the evaluations in the environmental assessments (under those guidelines that do not require site characterization as a prerequisite for application) as to whether such sites are suitable for development as repositories, it has been preliminarily determined that the recommended sites are suitable for development as repositories.