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A METHOD FOR SCREENING THE NEVADA TEST SITE AND CONTIGUOUS AREAS FOR NUCLEAR WASTE REPOSITORY LOCATIONS

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NUCLEAR WASTE STORAGE
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A METHOD FOR SCREENING THE NEVADA TEST SITE AND CONTIGUOUS AREAS FOR NUCLEAR WASTE REPOSITORY LOCATIONS*

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INTRODUCTION

This report outlines the general concepts of a technical method for systematic screening of the Nevada Test Site (NTS), Nye County, Nevada, for potentially suitable nuclear waste repository locations. After a ~~general~~ discussion of the organization and purpose of the current screening activity, the report ~~will~~ addresses the steps of the screening method. These steps include: (1) hierarchically organizing technical objectives for repository performance (an objectives tree); (2) identifying and mapping pertinent physical characteristics of a site and its setting (attributes); (3) relating the physical conditions to the objectives (favorability curves); (4) identifying alternative locations and numerically evaluating their relative merits; (5) investigating the effects of subjective judgements on the evaluations (sensitivity analyses); and (6) documenting the assumptions, logic,

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and results of the method. Detailed discussion of the decision-making methodology embodied by the screening method is available in other sources.(1,2,3)

Organization

The Department of Energy's (DOE) Nevada Nuclear Waste Storage Investigations (NNWSI) Project Office is formally responsible for evaluating the suitability of the NTS for a mined repository that would be constructed deep underground to isolate commercial spent nuclear fuel or high-level radioactive waste.[4-6] The NNWSI are managed by the Nevada Operations Office (NV) of the DOE. Technical support is provided by Sandia National Laboratories, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, the U.S. Geological Survey and Westinghouse Corporation. The NNWSI are part of the DOE's National Waste Terminal Storage Program (NWTS) which is charged with the responsibility to ~~manage~~ develop the technology which will ultimately be used to ~~and eventually~~ dispose of wastes from the nation's commercial nuclear activities.

Organization and use of specific screening information will be coordinated by the NNWSI Technical Overview Contractor (Figure 1). Continual review and guidance will be provided by the NNWSI Site Evaluation Working Group (SEWG). The SEWG will evaluate screening results and recommend future characterization options to the NNWSI Site Evaluation Steering Committee. The Steering Committee, in turn, will recommend a specific course of action regarding repository siting activities at the NTS to the manager of the Nevada Operations Office.

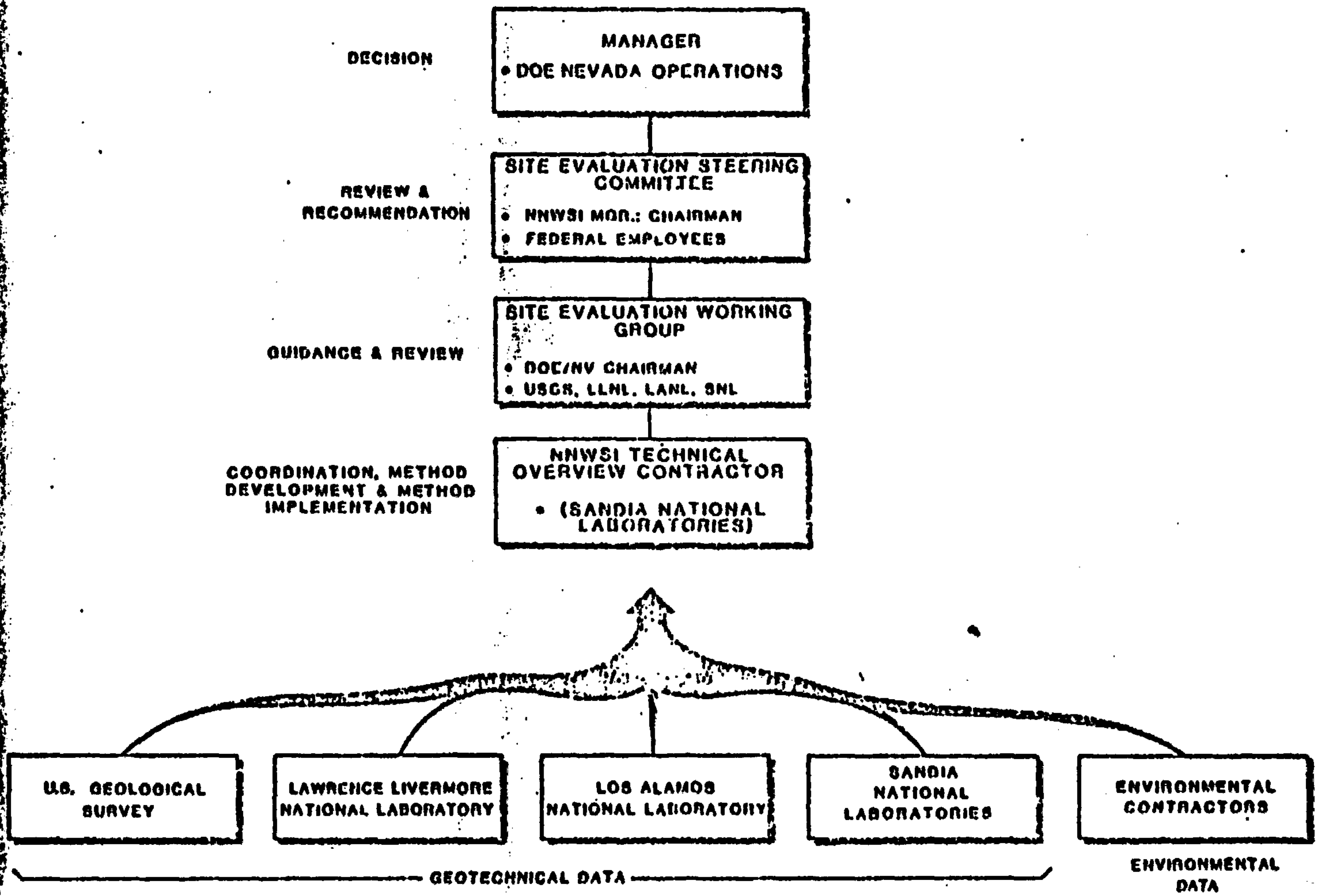

Figure 1. Organization of NNWSI location screening activity

Purpose

The purpose of the NNWSI screening activity is to formally identify geographic locations at the NTS which, from current information, merit further characterization and evaluation for a commercial nuclear waste repository. Siting activities are currently limited to a region encompassing the southwest portion of the NTS to avoid interference with the NTS prime mission, nuclear weapons testing[5] (Figure 2).

The proposed screening method will not assess potential repository locations for absolute suitability. Rather it will identify where potentially suitable locations exist and will simultaneously compare their relative merits. It is both premature and unwise at this time to presume a capability for assessing suitability on an absolute basis. This is the view of the NNWSI Technical Overview Contractor considering the lack of absolute standards based on health consequences for each of the many repository siting factors currently documented by various organizations.[5-15] In addition, comprehensive site data and engineering designs required for reliable consequence analysis are not yet available. Only after detailed site characterization following location selection will information be adequate to support safety assessments in terms of absolute and regulatory requirements. The current phase of screening will provide the rationale for focusing exploration and characterization efforts on that location or locations which, based on the best judgements of those involved, will ultimately prove suitable to safeguard public health and safety and environmental integrity.

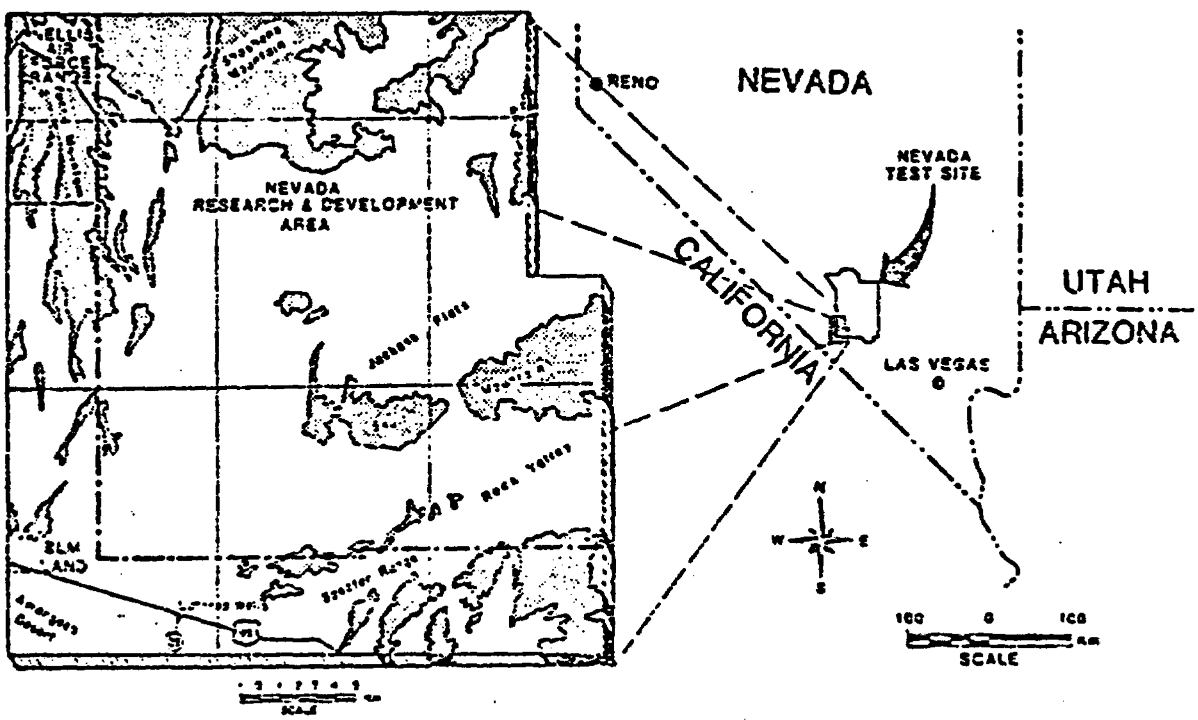

Figure 2. NNWSI repository location screening area

Some decision risk is unavoidable. Nonetheless, the screening method outlined here, when properly supported by a broad range of technical disciplines, will reduce the chance that subsequent characterization efforts will be expended on an unsuitable location.

Screening will be accomplished by analyzing the siting problem into component objectives, physical attributes, and criteria; evaluating each part separately; and recombining them for comprehensive comparison of alternate locations. For any given location, the possibility is reduced that an unacceptable flaw will be overlooked as each factor is individually considered. Conversely, the chance that a mitigating circumstance for an apparently unacceptable flaw will be overlooked and a suitable location needlessly rejected is reduced when the component siting factors are recombined to rate alternate locations.

The screening activity will rely on data from past and current NNWSI exploratory field work and laboratory studies, as well as other readily available information. Results will be documented in a Screening Summary and Recommendation Report which will provide a basis for deciding whether to proceed with further repository siting studies on the NTS, and if so, where exploration or further investigation should be concentrated, ~~both geographically and perhaps topically~~.

NATURE OF THE SCREENING PROBLEM

Relation to the NWTS Site Characterization Process

Repository siting activities on the NTS are just one part of the comprehensive national effort to identify and characterize suitable repository sites and to develop engineered systems compatible with the site conditions. The sequential phases of the national site selection and characterization process, as outlined in the DOE's testimony before NRC[5,6] include:

1. National surveys to identify favorable regions (up to several states in extent) for repository development;
2. Regional surveys to identify areas (up to 1,000 square miles);
3. Area surveys, including limited drilling and field work, to identify locations (up to 30 square miles);
4. Location studies including extensive drilling, testing, and field work, and conceptual repository design to identify specific sites (nominally 10 square miles);
5. Banking of a number of candidate repository sites;
6. Concurrent detailed site studies including subsurface exploration, testing at the base of a large diameter shaft and detailed facility design; and
7. Selection of a site or sites for application to the NRC for a license to construct a repository.

The size of the NTS approximates that of an "area" in the NWTS site selection process. This and its historical use for nuclear activities prompted the DOE to classify the NTS as an "area" not requiring identification by previous geographic screening.[5,6] Accordingly, the first screening step at the NTS, and the subject of this document, is to develop a method for evaluating the NTS area and identifying locations for further study. A decision to proceed will initiate geologic and environmental studies of the location-specific phase of the NWTS site characterization process.

General Considerations

Several considerations affect the selection of a method suitable for screening the NTS (or any other area) for repository locations. First, the screening process must be able to objectively distinguish among alternate locations with respect to a set of multiple and commonly competing objectives for repository performance. A compatible set of usable, discriminating site selection criteria must be able to be derived from these objectives. Broad statements such as finding sites "compatible with waste containment, isolation, and retrieval"[6] provide useful guidelines for location screening, but they cannot distinguish objectively among the relative merits of alternate locations. Therefore, criteria are needed which specify what is meant by "compatible," "adversely affect" and other subjective statements of desires in previously published general guidelines.[7-13] Because consensus on the content and importance of competing objectives and criteria will be difficult, if not impossible, to obtain, the method should include a means to evaluate the effects of criteria assumptions on screening results.

Second, existing information about the many physical factors considered important for repository siting must be organized in a consistent structure. Only then can criteria systematically be applied to an information base to identify more and less favorable locations.

Third, screening will be based on complex information characterized by varying degrees of uncertainty, disparity, and reliability. Data about the three-dimensional characteristics of the geologic hydrologic, and environmental settings are available only for sparsely distributed locations throughout the screening area. Information also varies about potential repository host rocks with respect to their geographic distribution, phenomenological responses, and transferability of modeling characteristics from laboratory to in-situ environments. Therefore, many unavoidable judgements and assumptions will be contained in the information base, and the ability to deal with this will be crucial to the screening results.

Finally, the screening method must be organized in a manner that allows interested parties, including regulatory agencies, to observe and assess the effects of assumptions, analysis logic, data uncertainties, professional opinions, and criteria definitions on the screening results. These basic considerations were paramount in the design of the screening method being applied at the NTS.

PERFORMANCE OBJECTIVES

The goal for radioactive waste disposal as expressed in the DOE's testimony to the Nuclear Regulatory Commission is "the effective isolation of radionuclides from the environment in a safe and environmentally acceptable manner."[5] Specific performance objectives by which a site will be judged by DOE prior to application for a construction permit are to demonstrate to DOE's satisfaction that:[5]

1. "Waste containment* within the immediate vicinity of initial emplacement should be virtually complete during the period

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*Containment in this context refers to a capability for restricting the wastes within prescribed boundaries (e.g., the engineered waste package which will be emplaced in the floor or walls of underground tunnels).

when radiation and thermal output are dominated by fission product decay. Any loss of containment should be a gradual process which results in very small fractional waste inventory release rates extending over very long release times, i.e., catastrophic losses of containment should not occur."

2. "Disposal systems should provide reasonable assurance that wastes will be isolated* from the accessible environment for a period of at least 10,000 years with no prediction of significant decreases in isolation beyond that time."

3. "Risks during the operating phase of waste disposal systems should not be greater than those allowed for other nuclear fuel cycle facilities. Appropriate regulatory requirements established for other fuel cycle facilities of a like nature should be met."

4. "The environmental impacts associated with waste disposal systems should be mitigated to the extent reasonably achievable."

5. "The waste disposal system design and the analytical methods used to develop and demonstrate system effectiveness should be sufficiently conservative to compensate for residual design, operational, and long-term predictive uncertainties of potential importance to system effectiveness, and should provide reasonable assurance that regulatory standards will be met."

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*Isolation in this context refers to the capability of natural environment to prevent the migration of unacceptable amounts of waste to human populations.

6. "Waste disposal systems selected for implementation should be based upon a level of technology that can be implemented within a reasonable period of time, should not depend upon scientific breakthroughs, should be able to be assessed with current capabilities, and should not require active maintenance or surveillance for unreasonable times into the future."

7. "Waste disposal concepts selected for implementation should be independent of the size of the nuclear industry and of the resolution of specific fuel-cycle or reactor-design issues and should be compatible with national policies."

Only the first four objectives are directly useful for distinguishing the relative merit of alternative geographic locations (Figure 3). The last three are overriding considerations applicable to any and all potential sites and siting processes. By assuming certain limits for engineering flexibility, desirable and undesirable conditions of the natural system can be defined with respect to each of the major location-distinguishing performance objectives. These conditions form the basis for a set of sub-objectives around which the NNWSI screening method is structured, allowing all screening judgements and rationale to be directly traceable to the four major objectives.

Objectives Tree

Repository performance objectives are organized into a hierarchical format referred to as an "objectives tree" (Figure 4). The tree shows, from general to specific, how each of the four major performance objectives is to be achieved by searching

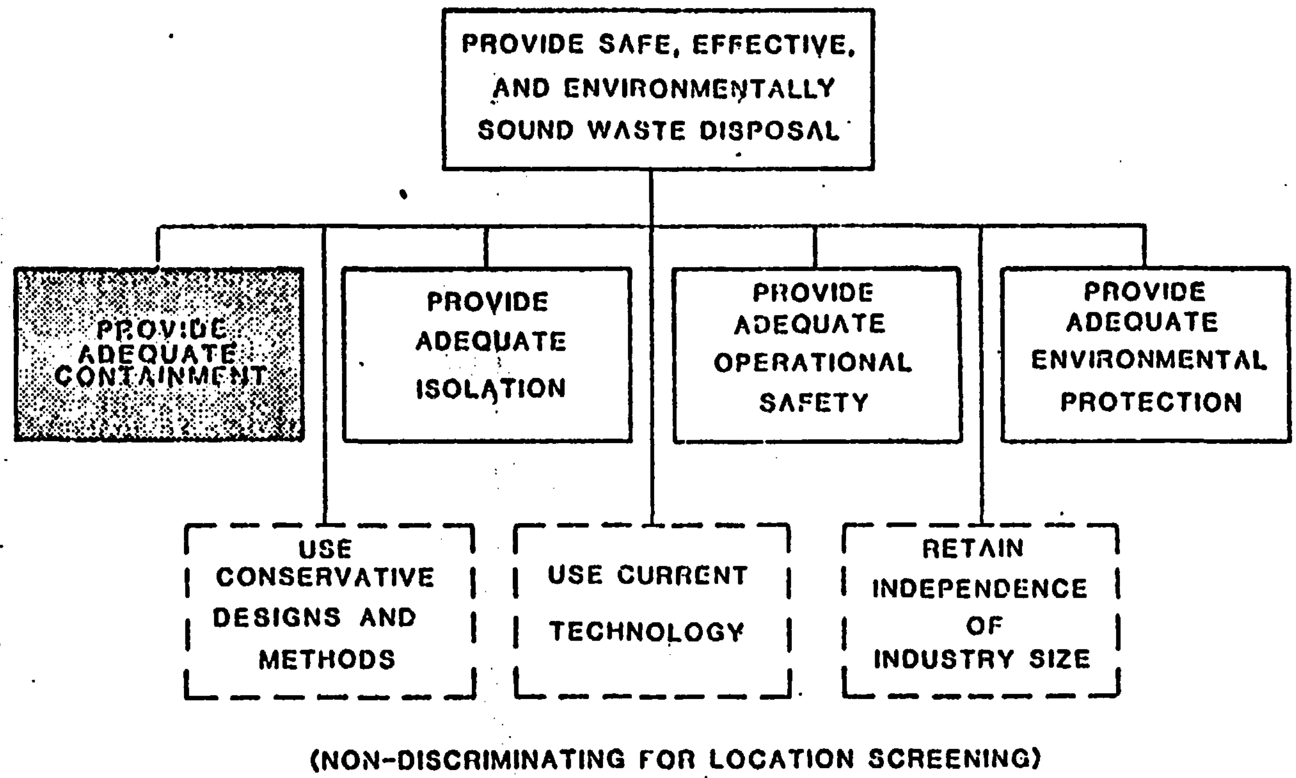


Figure 3. Major performance objectives for guiding NNWSI repository location screening. Lower levels of containment objectives (shading) are developed in Figure 4.

for locations which optimize the chances for satisfactory performance with respect to individual sub-objectives or "criteria." An objective tree is constructed by asking how each upper-level objective is to be accomplished (Figure 4). The answer, or answers, must be comprehensive. They then constitute a set of inclusive objectives of the next lower level. For example, the question, "How can the DOE's objective 1, adequate containment, be achieved?", can be answered by considering the things that may result in loss of containment and then setting as sub-objectives the avoidance of those things. Because containment is a state of being, either a process or an event* is required to change that state. Thus, avoidance of disruptive processes is one sub-objective for preserving containment while avoidance of disruptive events is another. Together, these two sub-objectives exploit all possibilities by which containment can be lost.

In turn, the questions, "How can disruptive events and disruptive processes be avoided?" form the basis for constructing the next lower level on the tree. Two processes, chemical and mechanical, exploit the processes by which containment can be lost and thus constitute the sub-objectives for the "process" branch of the containment tree. Types of events which might cause loss of containment are numerous, but seismic, volcanic, erosional, and human intrusional are considered most credible. Avoidance of these were thus selected as the lower-level objectives of the "event"

*The distinction between processes and events is arbitrary depending on the temporal and spatial scale of concern. For the purposes of this analysis, processes are considered to require long times to achieve equilibrium relative to operational concerns, whereas events are defined as reaching completion in shorter times.

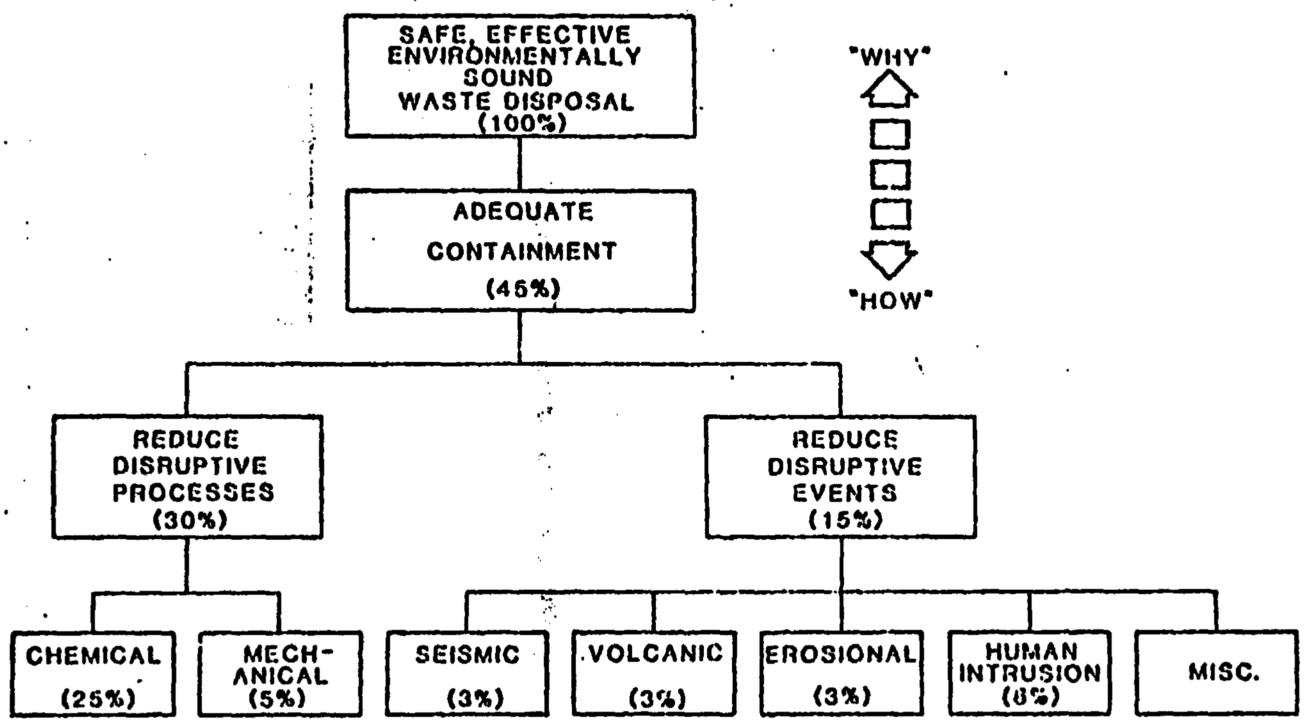


Figure 4. Example "containment" branch of an objectives tree. Percentages are hypothetical weighting factors discussed later under the heading "Rating of Alternatives."

branch of the containment tree. A category of miscellaneous events was included in the tree to meet the requirement for comprehensive listing of all possible answers to the question, "How?" The question "Why are certain concerns necessary or important?" can also be answered by inspection of an objectives tree. Each higher-level objective provides the rationale for pursuing its set of lower-level objectives.

It should be noted that the lower level objectives themselves could be divided into sets of sub-objectives. Seismic events, for example, could be separated into: (1) fault movements which may shear waste packages and (2) vibratory ground motion which may cause failure of the packages. We stopped developing the tree at the second level below each of the four major DOE performance objectives because that was judged sufficient to resolve the problem into components compatible with evaluation, given the state of knowledge about the NTS and its surroundings.

It should also be noted that there is no unique solution to the problem of separating major objectives into sets of hierarchical sub-objectives. Although different approaches to organizing an objectives tree are possible, if differently organized trees are comprehensive of concerns relevant to a given problem, they will converge at lower levels on the information required to evaluate the problem. The lowest level sub-objectives of the NNWSI screening are consistent with requirements for the natural system outlined in the NWTS "Site Performance Criteria"[7] and other published repository siting criteria documents.[8-13]

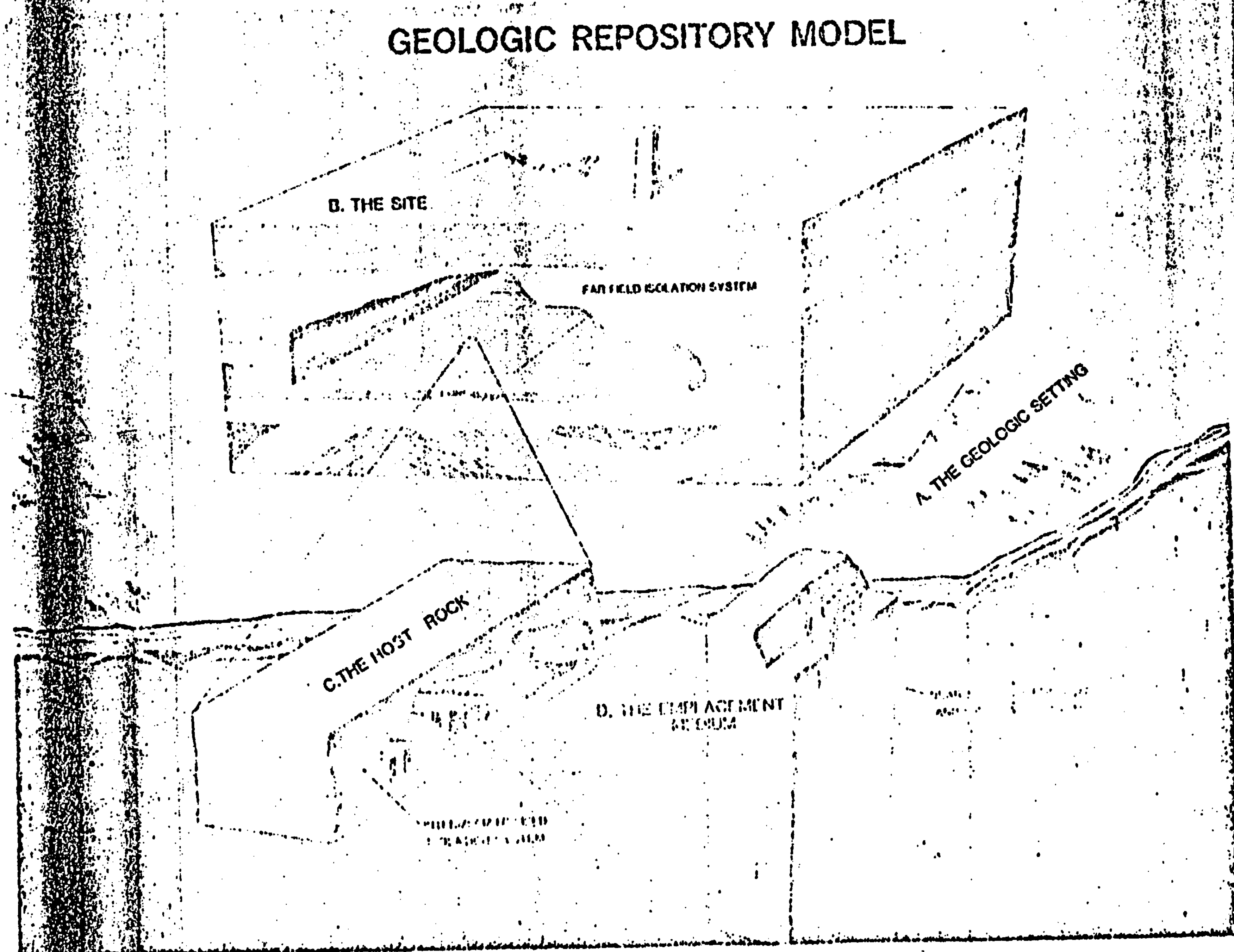
ATTRIBUTES

Repository Model

To meet its objectives, particularly NWTS objective 6, "use of current technology," DOE has chosen to concentrate nuclear waste management efforts on one particular disposal concept, mined geologic repositories.[5,16-18] Accordingly, NNWSI siting activities are currently directed toward identifying locations compatible with the characteristics of a mined repository. This concept calls for emplacing specially packaged solid radioactive waste forms in holes drilled into the walls or floors of tunnels hundreds of meters below the ground surface (Figure 5).

To enhance confidence that a mined repository will perform as intended, the repository concept has been separated into components, each of which can be independently and impartially assessed in terms of its contribution to performance with respect to each element of the objectives tree. Most generally, the components are the engineered system and the natural system. The engineered system is composed of the waste form, its package, the subsurface excavations, the waste emplacement design, waste transport mechanisms, and waste handling facilities, both at the earth's surface and within the excavations. Details of the engineered system cannot be determined until a site has been selected. Therefore, consideration of alternative engineering concepts must be postponed until a specific location is selected and investigated. For this reason only natural conditions of the NTS and its surroundings will be the basis for location screening.

Figure 5. General model of a mined geologic repository.



The natural system is composed of geologic, hydrologic, meteorologic, and ecologic systems. These systems are generally beyond engineering control and must therefore, be selected, rather than designed, for properties which inhibit mobilization, subsurface transport, and surface dispersal of radioactive contaminants should the engineered components fail. Properties of the natural system which allow an evaluation of the degree to which portions of the NTS screening area satisfy the lower-level objectives on the tree have been organized according to a hierarchy of topical categories ranging from the far field general setting of a site to the very near field waste emplacement medium. This hierarchy is illustrated in Figure 6.

Attribute Maps

These topical categories of natural features, referred to as "attributes," must be measurable and mappable conditions or properties of the natural system and must provide information suitable for evaluating performance with respect to one or more lower level objectives on the objectives tree.

For instance, one lower level objective is to reduce hazards associated with volcanic activity; a relevant and measurable parameter of the natural system for evaluating that objective might be the distance from the most recently active volcanic belts or the likelihood of volcanism as a function of local structural conditions. A separate map will be compiled for each attribute identified as suitable for discriminating among locations in the SW NTS. Selection of appropriate measuring parameters for the attributes as well as development of the maps will be the responsibility of

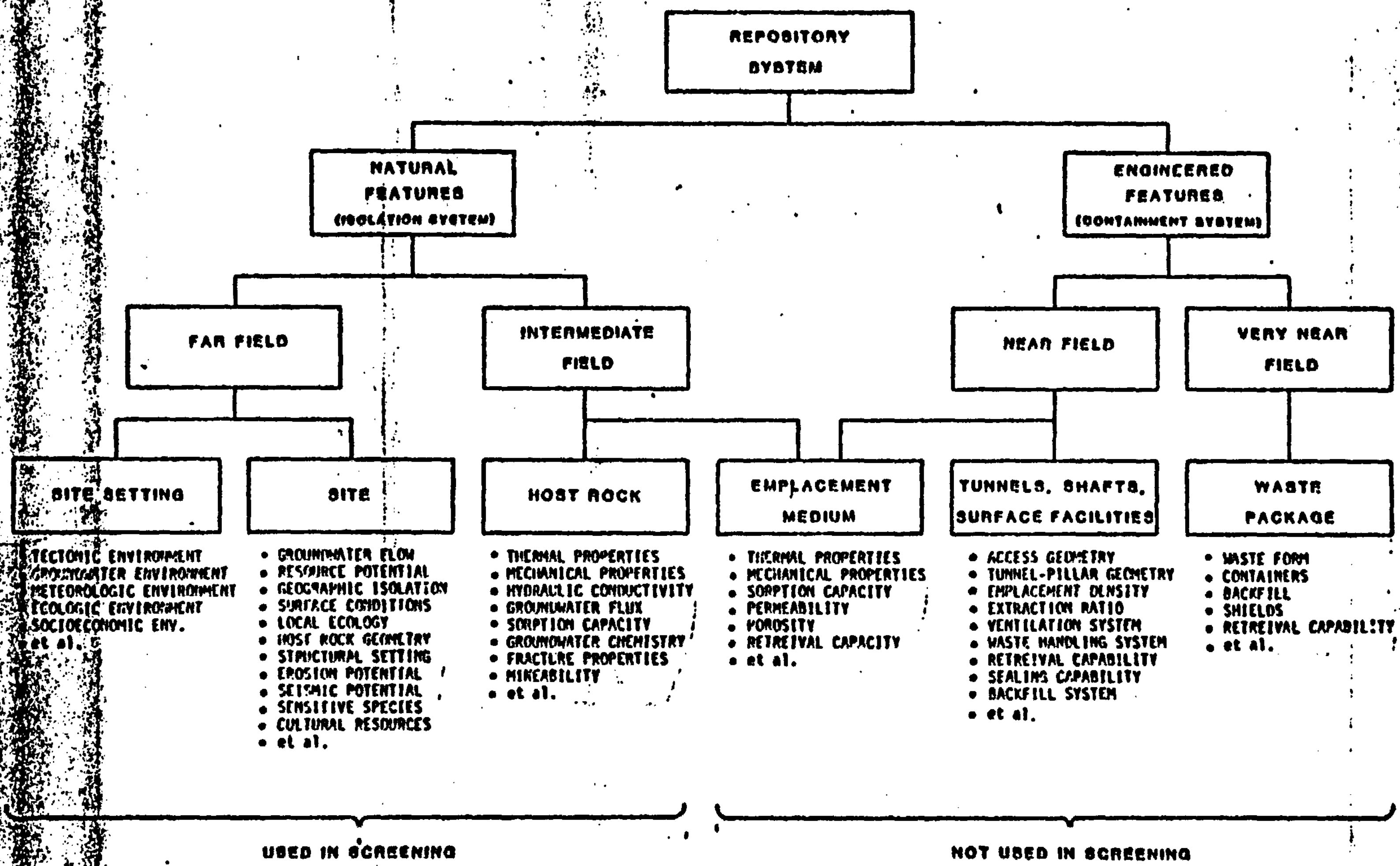


Figure 6. Hierarchy of repository attributes. Note: the emplacement medium is distinguished from the host rock to accentuate the scale at which the engineered and natural systems converge.

appropriate experts within the NNWSI project and others familiar with the attributes in question. Considerable professional judgement will be required in both these endeavors.

Because much information from current repository exploration and characterization studies at the NTS is either preliminary, sparsely distributed or available only for isolated portions of the study area, a range of confidence in the mapping data is unavoidable. Confidence in the supporting information commonly has not been treated in a systematic manner in previous site screening analyses. This is of concern because alternate screening locations may appear similar with respect to overall suitability, but the ratings may be based on information sources of varying reliability. We believe that systematic consideration of such confidence differences is important to a decision on repository siting. Therefore, we hope to prepare maps analogous to the reliability diagrams accompanying many AMS and USGS 1° x 2° topographic quadrangles in order to express judgements regarding confidence in the mapped data. If we apply this option, confidence estimates will be provided by the same technical personnel who will prepare the maps of attribute measures. Techniques for evaluating and mapping confidence in the screening information will be developed after the attribute maps are completed and assessed.

<u>Relation of Attributes to Objectives</u>

A matrix which relates performance objectives to screening attributes (Figure 7) establishes the applicability of each attribute to evaluating the suitability of each location with

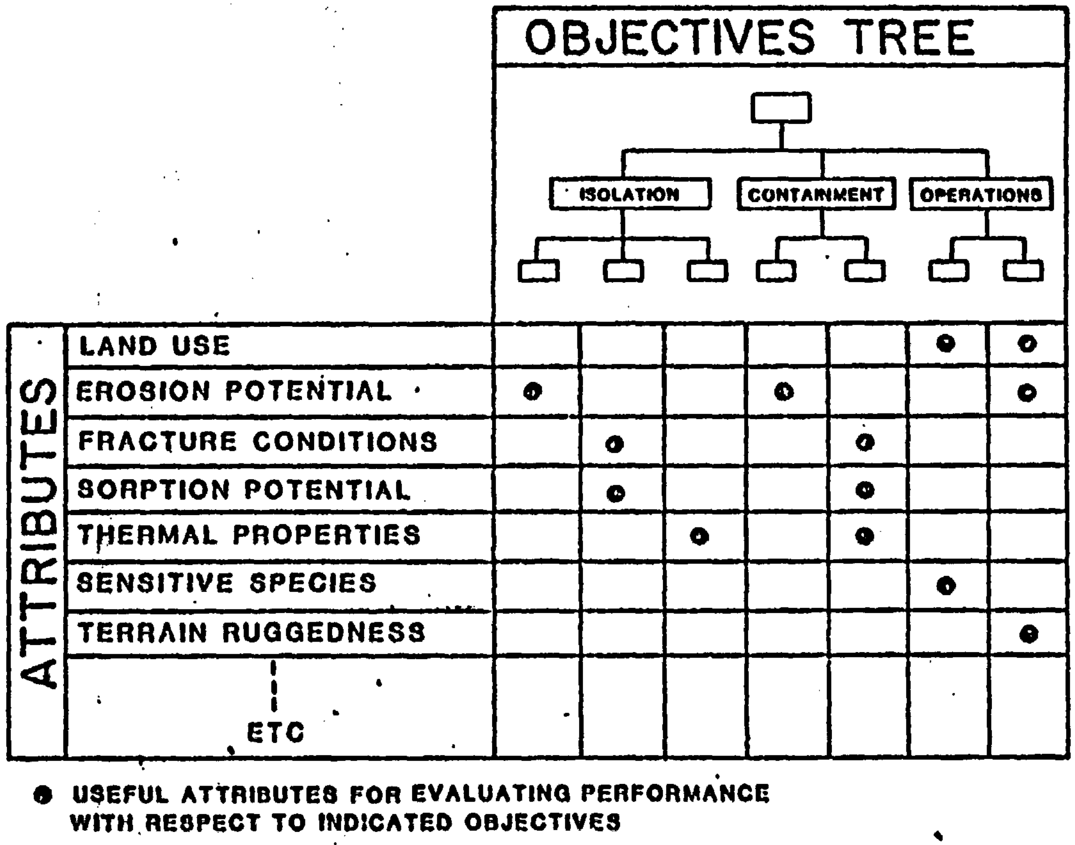


Figure 7. Schematic matrix illustrating how physical attributes of the natural system relate to evaluating one or more performance objectives.

respect to individual lower-level objectives. This matrix systematically resolves the large, complex screening problem into smaller, more manageable subsets. The matrix also provides a convenient framework for documenting the screening analysis in a logical and comprehensive fashion.

Mapping parameters for the attributes will be specially selected to organize natural system data within a context appropriate for evaluating the objectives. These mapping parameters will not embody judgements of favorability. For example, thermal conductivity of a potential host rock is a consideration for evaluating a repository's mechanical and chemical performance; it may be measured and mapped. However, a map of thermal conductivity values expresses physical facts about the screening area and does not convey information about whether the physical fact is good or bad for repository performance. That assessment requires a separate judgement.

FAVORABILITY FUNCTIONS

Favorability functions provide the required links between factual conditions of the physical world and the desired conditions for repository performance. Such functions will be developed in a manner which ties conditions of the mapped attributes to desires expressed by lower-level objectives. These functions are a form of siting criteria in the following way. The objectives define a set of desirable goals to be pursued; the attribute maps express how physical conditions of the natural system are distributed throughout the screening area; and the favorability functions indicate the degree to which the physical conditions are compatible with the goals.

A separate favorability function will be developed for each attribute. Each function can be expressed as a graph. Units on the abscissa must be identical to mapping units for the attributes; the ordinate is a standardized scale of favorability with respect to a particular performance objective, and for this application will be defined by values ranging from 0 (relatively unfavorable) to 10 (relatively favorable) (Figure 8).

A single attribute may apply to different objectives in different ways and require more than one favorability function. Porosity, an attribute of the geohydrologic system, may in some cases be undesirable with respect to groundwater flow time for some rock types, but desirable with respect to sorptive capacity.

This method thus allows judgements about natural system favorability with respect to separate objectives to be made independently from judgements about the physical conditions of nature as represented on the attribute maps. Favorability functions also allow one to systematically consider "more favorable" versus "less favorable" conditions and thereby increase the information upon which decisions are made, as opposed to evaluations based solely on a set of exclusionary conditions. If appropriate, threshold levels can be included in the functions to permit exclusionary conditions of the natural environment to be considered.

Assigning relative favorability values to attribute properties for each appropriate objective will require considerable insight and judgement on the part of the experts and managers of the

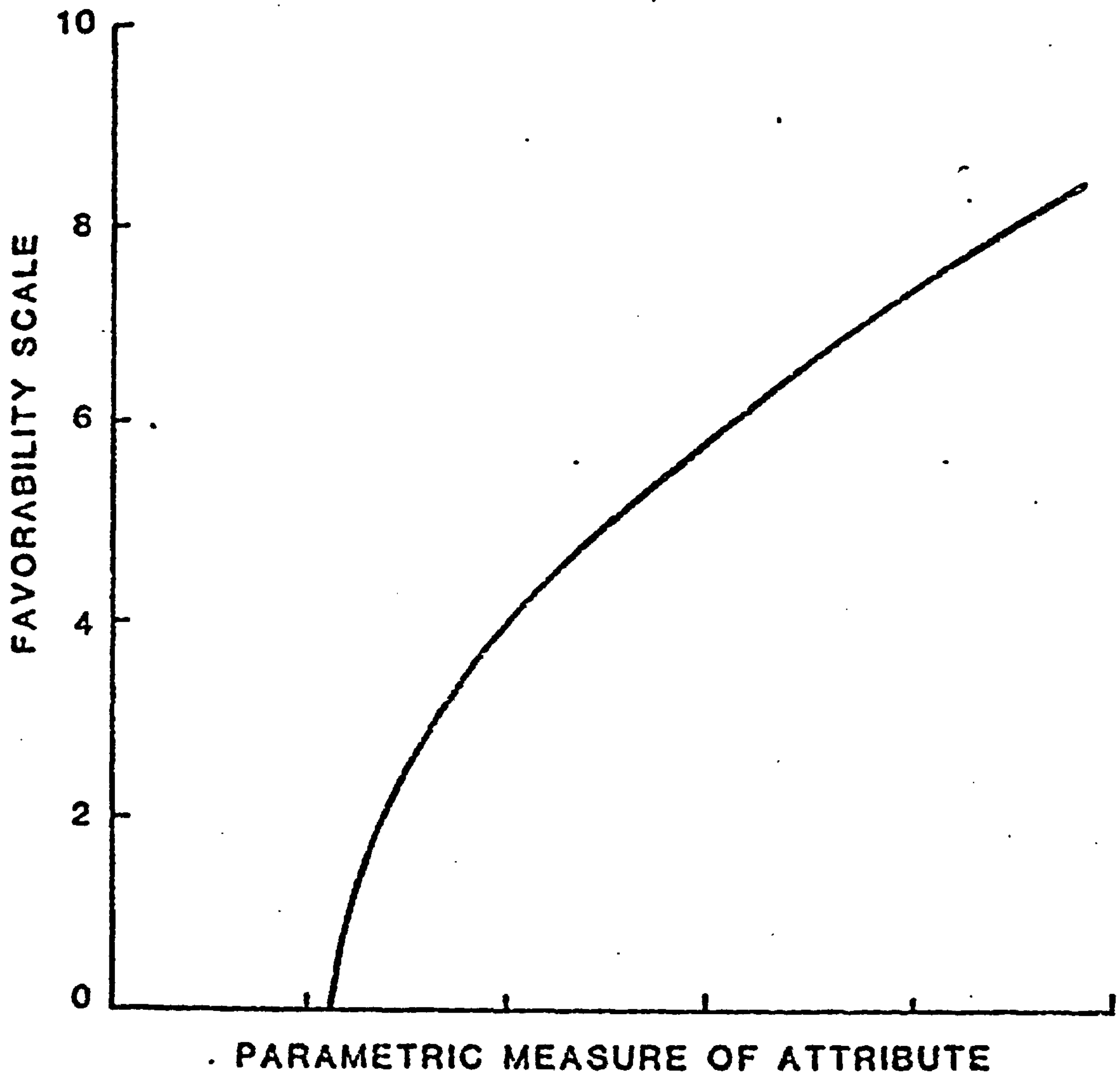


Figure 8. General features of a favorability function relating measures of an attribute to a scaled favorability rating.

NNWSI project. Concensus on the exact favorability values for individual functions will probably be elusive, though general trends are expected to be generally agreed upon.

Because the predicted ultimate radiological dose-to-man health impact is the primary criterion that constrains long-term suitability of a repository, any design or siting criteria for assurance of radiological safety phrased in terms of other factors are necessarily arbitrary. Unavoidable subjective judgements about the nature and geographic distribution of parameters of the mapped attribute conditions as well as judgements about the relationships of attributes to siting objectives must ultimately guide site screening and eventually site selection activities. The NNWSI screening method is designed to apply a systemmatic rationale to as many of these judgements as possible. Each earth science factor used to represent natural conditions considered in site screening will be reduced wherever possible to quantitative expressions. The presumed relationships of these expressions for attribute conditions to ultimate repository performance, as embodied by the favorability functions, must be the basis for location recommendations in the absence of a full safety assessment that couples all such expressions in a set of radiological dose-to-man predictive models. This emphasizes the difficulty in specifying criteria and exercising objective site selection prerogatives before the full nature and impacts of all site conditions are known.

Mapped qualitative expressions about existing natural conditions and the likelihood of hypothetical disruptive events will help standardize the attribute information base and guide the judgements of persons responsible for site suitability decisions. However, the possibility that the decisions may turn out to be wrong will inevitably persist. The only alternative is to delay location suitability judgements until enough data for each potential site has been collected to allow the full capabilities of a safety assessment to be exercised. Given that many potential locations exist and that unavoidable quantitative uncertainties will occur even in the most complete safety assessments, this alternative is unrealistic and counterproductive to the national effort to site and construct a repository. Therefore, the appropriate question is not "How can we guarantee, before full data collection, the selection of a safe site?", but "How can we standardize the incomplete information base for our judgemental selection process?"

The criteria (favorability functions) and data reduction methods discussed in this report are means used by the NNWSI before completion of a full safety assessment for guiding the identification of geological systems judged on current information to be capable of ultimately providing for acceptable repositories. Because this phase of NNWSI siting activity is a geographic screening designed to identify suitable locations for focusing exploration resources and is not a safety assessment (which will not be completed until after the data from subsequent characterization studies are available), no rigorous, comprehensive attempt will be made at this time to define favorability scales for all attributes in terms of rigid acceptability criteria. However, the method outlined here is adaptable to application of absolute quantitative criteria should consequence assessments or other analytical means become available that ~~will~~ would allow an absolute rating of physical conditions for repository performance.

EVALUATION OF ALTERNATE LOCATIONS

Definition of Alternative Screening Locations

Alternative geographic candidates for screening can be defined in a number of ways. One is by dividing the SW NTS into discrete geographic units based on potential host rock continuity at depths of interest. Another is by designating locations with similar physiographic (e.g., Skull Mountain, Jackass Flats, etc.), or geohydrologic characteristics. A more abstract technique involves dividing the SW NTS into a large number (a few thousand) of "resolution units" arranged upon an arbitrarily imposed geographic grid, such as quarter sections (1/2 mile by 1/2 mile). By this technique individual attribute maps are overlaid on the grid (Figure 9). The size of each grid unit is considerably smaller, perhaps by a factor of 10-30, than the area required for a repository. Each grid unit can be independently analyzed for suitability, and repository locations defined where an appropriate number of contiguous units with favorable ratings occur. This technique therefore both identifies and evaluates alternative locations thereby reducing the likelihood of bias from defining alternatives on a priori notions about location boundaries.

Many concerns about repository performance depend on the properties of the host rock in which wastes will be emplaced. Therefore, the NNWSI will combine a geographic grid with host rock occurrences to define alternative locations. [illegible] potential host rock in the SW NTS will be delineated where it occurs at

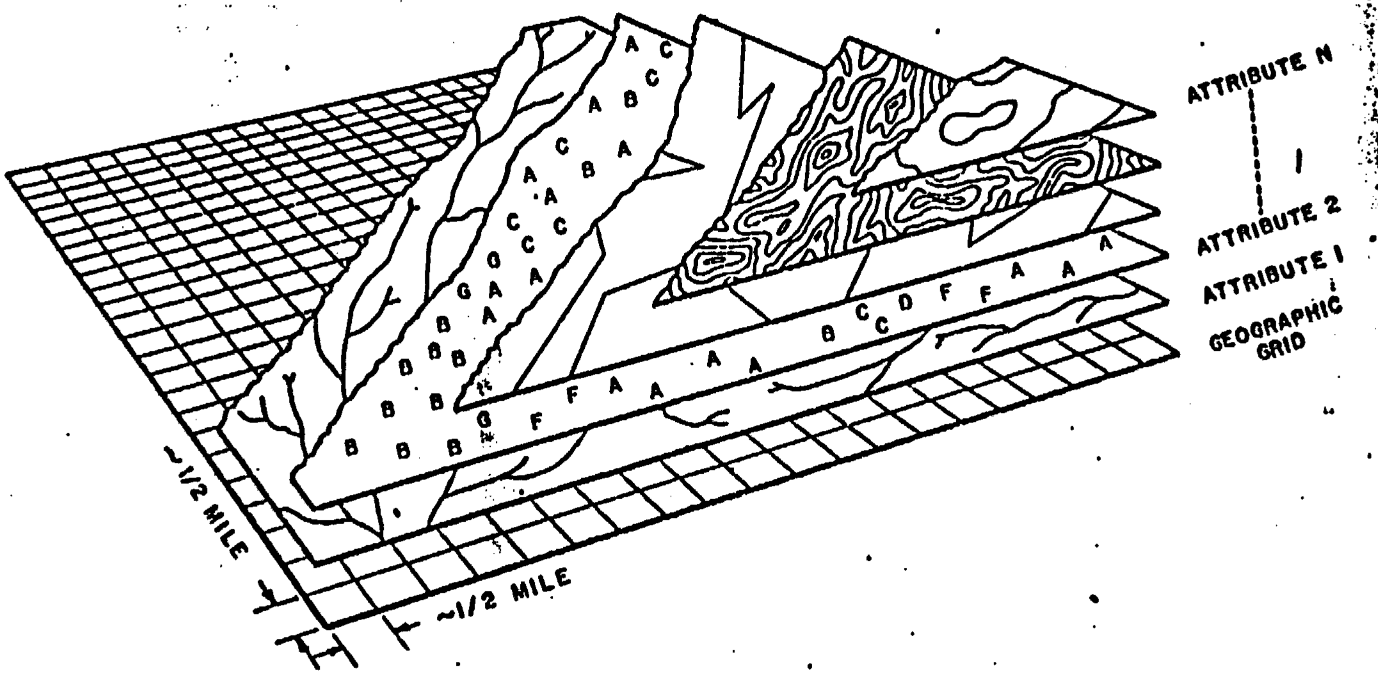


Figure 9. Schematic overlay of individual attributes on an arbitrary geographic grid encompassing a screening area.

appropriate depths and with sufficient thickness. A quarter section grid also will be constructed for the entire SW NTS screening area.

Attribute properties which depend on rock type will be assigned to grid elements corresponding to geographic occurrences of the appropriate rocks. Properties which vary independently of rock type, notably surface properties such as occurrences of sensitive species and terrain factors, will be assigned to grid elements throughout the screening area. In this manner, multiple grid "locations" corresponding to different host rocks at different depths can be evaluated at a single geographic position. Each grid element in the SW NTS will be independently analyzed, though some will not possess a designated host rock at depth while others will possess more than one. This hybrid technique for alternative definition permits consideration of the merits of locations lacking only a presumably satisfactory host rock. Of course, all subsurface areas have rocks. So a location that appears exceptionally favorable, except for the fact that it does not possess a presumably satisfactory host rock, may prompt a legitimate reconsideration of what constitutes acceptable host rock properties.

Rating of Alternatives

Evaluation of individual grid units will be performed by a set of simple computer algorithms. The procedure by which performance rating scores can be obtained for each geographic grid element can be generalized as:

1. determine the physical value of each attribute for each grid element from the attribute maps;
2. determine the favorability number for that attribute value by comparing the results of step 1 to the favorability functions; and
3. sum the individual favorability numbers for each geographic grid element according to the assigned weighting factors (discussed below).

Grid elements with higher total scores are more favorable. This process is illustrated in Figure 10 where rating scores are computed for a hypothetical screening area composed of four geographic grid elements, A, B, C, and D.

An important element of the screening method is illustrated on Figures 4 and 10; that is, the weighting of various performance objectives and attributes. In any analysis with multiple, competing objectives, such as repository siting, some objectives are considered more important than others. For example, should equal importance be given to desires to find sites with long ground water flow times to the biosphere and to find sites with minimal potential for meteorite impacts? In this extreme example the answer is obviously no; long flow paths are unequivocally more important. In fact, all separate objectives may be presumed to have a different relative importance to the overall goal of safe, environmentally sound, cost effective waste disposal. A system of weighting will be used to account for the differing importance of individual objectives. Assuming the overall problem of finding a satisfactory site has an importance of one hundred percent, then each lower-level

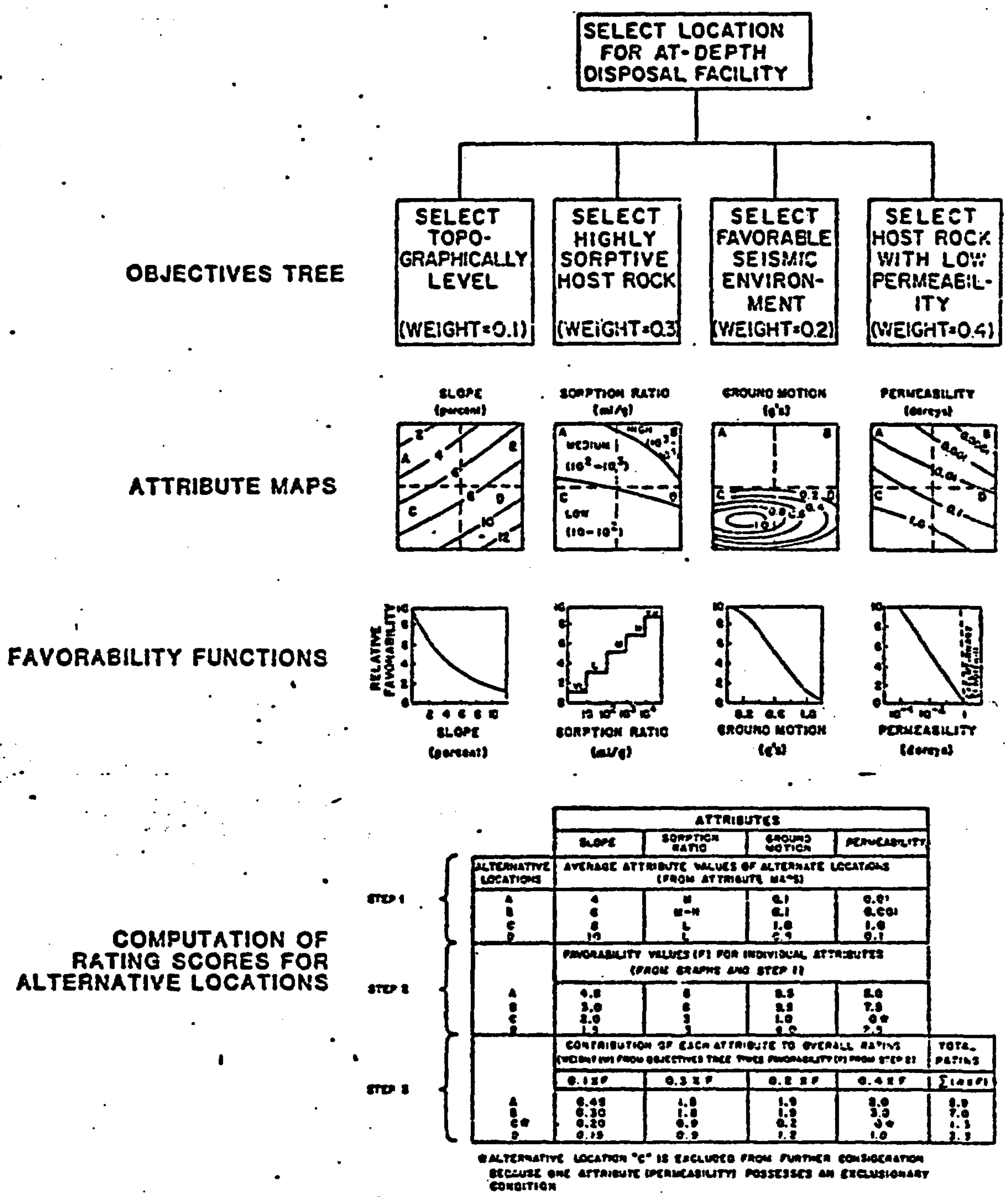


Figure 10. Example analysis showing the way components of the [illegible] NNWSI screening method are combined to obtain [illegible] rating score for each grid unit (A, B, C, and D).

sub-objective will have an importance that is some lower percentage. The sum of the weights for all sub-objectives of the same level will then be one hundred percent.

The hierarchical nature of the objectives tree facilitates assigning relative importance to each level of sub-objectives. The tree allows weighting to be approached by a series of iterations progressing from general to specific and alleviates the problem of attempting to determine in one step the relative weight of all lower-level objectives.

The favorability value of each attribute (step 2, Figure 10) will be multiplied by the weight of the objective which is addressed by that attribute (top row, Figure 10). The sum of the weighted favorability values thus forms the basis for rating of the alternative grid locations.

As with construction of favorability functions, determination of weighting values for objectives will require considerable insight and judgement. Management personnel as well as technical experts are required for this task, especially for considering the tradeoffs among higher level objectives, such as safety, environment, and construction cost.

Sensitivity Analyses

It is apparent that many judgements are required to support this screening method. First, expert opinions about physical conditions in the screening area and about the confidence one can place in the opinions must be recorded on attribute maps. Second, judgements are required about relative favorability on a scale of 0 to 10 regarding the various physical conditions mapped for each attribute. And finally but not least, are judgements about the relative importance of various performance objectives. Each of these judgements will affect the numerical results of the screening analysis. It is highly unlikely that satisfactory concensus can be achieved for each of the judgements to be made. Nonetheless, objective means are not available to alleviate the need for such judgements whether screening is performed by the method outlined in this paper or by any other.

To account for these subjective elements, sensitivity of the screening results will be evaluated for a range of reasonable judgements concerning the geographic distribution of attribute properties, the shape of favorability functions, and the relative importance of the performance objectives. Each of these parameters will be varied within reasonable limits and the effects on the ratings of alternate locations will be assessed.

In consequence, the screening activity will not produce a unique solution. Rather, the method will provide a decision-support base with a range of options defined by assumptions about attribute data, relative weights of performance objectives, and favorability functions. It will be incumbent on policy makers to determine which set of assumptions to follow. Given such decisions, the screening activity will highlight those locations having the highest overall potential for suitability for a repository and therefore the best locations for further exploration and characterization efforts. By assigning zero weights to some objectives it will be possible to use the screening method to investigate which locations are most suitable based on a limited set of specific attributes or objectives.

DOCUMENTATION

Each component activity of the screening process will be documented, including sources of information, assumptions, analytic logic and personnel used to construct the objectives tree, attribute maps, and favorability functions. The information will be recorded on individual data sheets for each objective, map and function. Data sheets will be organized and filed for easy retrieval. Computer algorithms used to digitize the data base and perform numerical evaluation of the screening area will also be documented. Different sets of assumptions used in sensitivity analyses will be recorded and location ratings associated with each set of assumptions will be preserved and filed. Based on the results of the sensitivity analysis, recommendations concerning the locations, if any, to be explored further will be summarized by the NNWSI Technical Overview Contractor in a Screening Summary and Recommendation Report and transmitted to the NNWSI Site Evaluation Working Group.

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