REPOSITORY SITE CHARACTERIZATION

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ABSTRACT

The characterization of candidate repository sites has a number of programmatic objectives. Principal among these is the acquisition of data:

a) to determine the suitability of a site relative to the DOE repository siting guidelines,

b) to support model development and calculations to determine the suitability of a site relative to the post closure criteria of the NRC and EPA,

c) to support the design of a disposal system, including the waste package and the engineered barrier system, as well as the shafts and underground openings of the repository.

In meeting the goals of site characterization, we have an obligation to conduct our investigations within an appropriate budget and schedule. This mandates that a well-constructed and systematic plan for field investigations be developed. Such a plan must fully account for the mechanisms which will control the radiologic performance in the repository. The plan must also flexibly and dynamically respond to the results of each step of field investigation, responding to the spatial variability of earth as well as to enhanced understandings of the performance of the disposal system. Such a plan must ensure that sufficient data are available to support the necessary probabilistic calculations of performance.

This paper explores the planning for field data acquisition with specific reference to requirements for demonstrations of the acceptable performance for disposal systems.

INTRODUCTION

The Department of Energy, having selected candidate repository sites in Texas, Nevada and Washington, is preparing to undertake the characterization of these sites to determine their suitability as repositories. This characterization process will require that systems engineering methods be applied both in the planning phase of this activity, as well as throughout the characterization process, to ensure a successful program. This process must be undertaken with full consideration of the nature of the disposal system, with consideration of the performance requirements imposed upon the disposal system, and with recognition of the need to complete the characterization process on a timely basis, and with an appropriate expenditure of funds. This paper addresses this process.

DISPOSAL SYSTEM CHARACTERISTICS

The repository system must rely upon both the engineered features as well as the capabilities of the natural earth system to successfully dispose of radioactive wastes. The disposal system's performance is inherently uncertain. This uncertainty exists due to four factors:

- spatial variability of earth
- temporal variability of the disposal system
- data uncertainty
- process and model uncertainty

The earth is spatially variable. The entire disposal system may comprise a disk with a diameter of 20 kilometers and a thickness of 1 kilometer. It is not possible to fully know the spatial variability of earth in a system of this size. Earth scientists must therefore make field measurements in the system, and assert the variability of the key characteristics of the system. Their confidence in these assertions will increase with the number of measurements made. However, the final representations of the system which are required for performance and licensing analyses will contain a residual uncertainty due, in part, to the subjectivity in the interpolations and extrapolations required in the process.

The disposal system's performance must be asserted over a 10,000 year period in order to demonstrate compliance with the Environmental Protection Agency's standard for acceptable radiological risk from a repository. The disposal system is temporally variable over this period. It is not possible to fully know how the disposal system will change over this time period. The temporal variability can be attributed to three factors:

- development and operation of the repository
- external influences of man
- earth changes

The placement of wastes into a repository represents the disturbance of an earth system which, thermodynamically, is at or nearly at equilibrium.

A number of disposal-related activities are the principal sources of this disturbance:

- introduction of oxygen with mining
- redistribution of stresses with mining
- introduction of construction and backfill materials
- dewatering of the disposal system
- ambient temperature change with ventilation
- radiation emitted from the wastes
- heat emitted from the wastes

Most of these factors can be quantified. However, quantification of the equilibration of the system following the introduction of these disturbances is less exact.

Over the 10,000 year performance period, man's external activities will influence the disposal system. These influences include:

- use of groundwater
- intentional or inadvertent intrusion
- climatological changes
- resource exploration or development

It is possible to quantify the probabilities and impacts of such influences, where such quantification, particularly of the probabilities, is subjective and hence retains a residual uncertainty. Such quantification is not made more certain with the acquisition of more field data, except to better understand the potential impacts of such changes. Hence, a residual uncertainty will remain in the asserted performance of the disposal system as a consequence of this factor.

The third source of temporal variability is changes in the earth system. While 10,000 years is not long in geologic time, it is possible that the earth could change over this period in such a manner as to influence numerical assertions of repository performance. Investments into field work can provide a better understanding of the changes which have occurred in the earth during the past. To the extent that such past changes can be quantified for periods substantially greater than 10,000 years in the past, the uncertainties in the prediction of future changes can be reduced. It must be recognized, however, that predictions of future changes in the earth are subjective, hence creating a source of residual uncertainty in asserted repository performance.

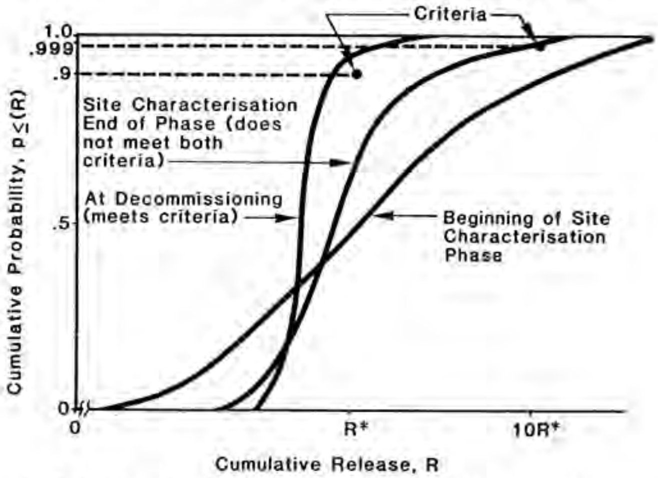
The third major source of uncertainty in the disposal system is derived from the data which are gathered to describe the disposal system. This uncertainty results from the processes associated with data acquisition and reduction. In large part, these uncertainties can be understood and quantified with investments of resources.

The fourth major source of uncertainty is process and model uncertainty. An acceptable disposal system is one in which, among other things, the long-term radiologic risk is mathematically represented as being less than the acceptable risk defined by the Environmental Protection Agency in 40CFR191. Such mathematical representations are based upon numerical models which predict long-term performance. These models and supporting data inherently contain the spatial, temporal and data *uncertainties* described above. Additionally, the models attempt to approximate earth processes. These approximations contain residual uncertainties founded in our inexact knowledge of each phenomenon which governs the performance of the disposal system. Investments made during the site characterization phase can reduce these uncertainties to the extent that processes can be better understood as a consequence of such work.

REPOSITORY DEVELOPMENT PROGRESSION

Throughout the development of a repository system, more knowledge is gained about the performance of the disposal system. Thus, the state of knowledge at the completion of the site characterization program will change by the time repository operations are complete. The Nuclear Regulatory Commission explicitly factors this gain into its repository regulations by requiring that a performance confirmation program be undertaken during the operation phase of the repository. The regulations also reflect this in addressing the retrievability of wastes. Implicit in these two portions of the regulations is that the Department of Energy will gain knowledge about the disposal system after it is licensed, and that such knowledge will either support the permanent disposal of wastes, or will dictate that the wastes be removed.

Thus, the Department of Energy will have to mathematically track its gain (or loss) in confidence in the performance of the disposal system throughout the development and operation of the system. This change in confidence is represented in Figs. 1 and 2. The corollary to this observation,



R* & 10R*: Allowable cumulative radionuclide releases as defined by 40CFR191, Table 1 - Appendix A

Fig. 1 Change in Level of Confidence.

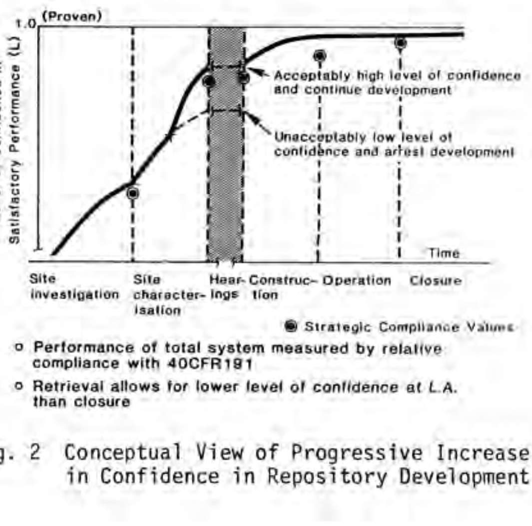


Fig. 2 Conceptual View of Progressive Increase in Confidence in Repository Development.

however, is that the uncertainty in repository performance which is quantified at the time of license application, and which is founded in either the sources of uncertainty previously described, or in the subjective assumptions required to complete performance calculations, must continually be subjected to reexamination. If that uncertainty grows, following the placement of wastes, to an unacceptable level, wastes will have to be removed, and the site abandoned.

REPOSITORY PERFORMANCE REQUIREMENTS

The radiologic performance of a disposal system must be considered in two phases: preclosure and postclosure. The Environmental Protection Agency in 40CFR191 has established the acceptable radiologic performance of the system for both phases.

Preclosure radiologic performance is established in Part A of 40CFR191. This requirement is stated in deterministic terms for radiologic exposure to the general public. The Nuclear Regulatory Commission has established regulations which implement this requirement, and has expanded them to limit the exposure of the work force. As these requirements are deterministic, assertions of compliance are based in traditional engineering practices. Further, compliance will be measured and demonstrated during the operation of the system.

Postclosure radiologic performance is established in Part B of 40CFR191. This requirement is probabilistic in nature, and hence approximates a statement of acceptable risk of the disposal system. This requirement is shown diagrammatically in Fig. 3. The requirement is that the cumulative probability that the stated cumulative, 10,000 year release from the disposal system must be no higher than 0.1, and that the cumulative probability of a ten-fold increase in this release must be less than 0.001. The Nuclear Regulatory Commission's regulations, while incorporating this requirement by reference, establishes a series of deterministic surrogates of long-term performance. The regulations are implicitly more conservative than the Environmental Protection Agency standard, except that the regulations are deterministic. It is not clear how the Commission will deal with the probabilistic nature of the performance of the disposal system's components, but in that it has not established acceptable probabilities for each standard, implementation will be subjective on the part of the Commission.

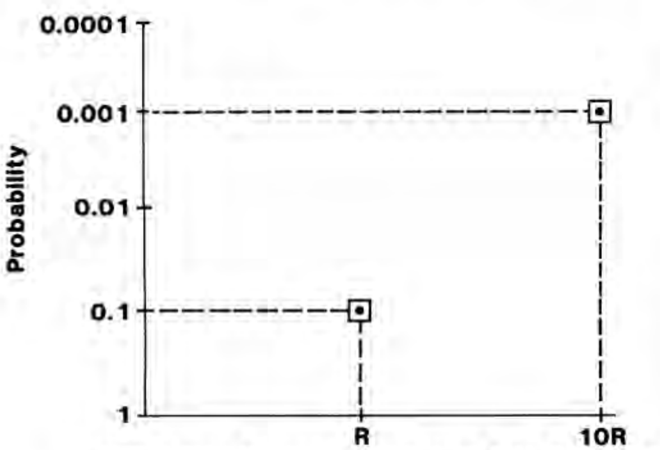


Fig. 3 Postclosure Requirements.

The Department of Energy has chosen to further expand both the preclosure and postclosure requirements for the disposal system. The first expansion is contained in the Department's Repository Siting Guidelines in 10CFR960. These guidelines, which were implemented in compliance with the Nuclear Waste Policy Act, are deterministic performance requirements for components of the disposal system. While 10CFR960 has an equivalent force of law, it is only applicable until the disposal system has been selected. It has no formal force following repository selection. The second expansion, done on an administrative basis by the Department, is reflected in the repository issues established in the Mission Plan, and expanded in DOE/RW-0101. The resolution of these issues forms the planning basis for repository site characterization.

SITE CHARACTERIZATION PROCESS

The site characterization process is more than the acquisition of data. The objectives of site characterization can be stated in the questions that follow:

1. Can the performance of the disposal system be asserted to be acceptable?
2. Can the assertions of performance be defended?
3. How much will the disposal system cost to build and operate?
4. How long will it take to build the disposal system?

The previous sections of this paper have shown that:

- the performance of the disposal system is inherently uncertain; and
- the requirements for repository performance are both probabilistic and deterministic.

Given these factors, the complexity of the disposal system, and the large cost and time period involved in characterizing the disposal system, it is evident that an essential part of the site characterization process is the development of a comprehensive and defensible plan. This plan must begin with an explicit statement of objectives. These objectives must be stated quantitatively and, where necessary, probabilistically. The process must also begin with a complete understanding of the current models, designs and data base for each site, as well as a numerical assertion of the probabilistic performance of the disposal system.

The next step in the process is fundamentally an investment decision. It is not fiscally prudent to pursue the development of a disposal system in which each component can, in the absence of all other components, meet the overall system requirements. Thus, early in the planning process, initial judgments must be made about the level of performance to be gained from each component of the system. These judgments must reflect the initial performance of each component, the performance which might be attained with further investments, the time required to achieve such performance gains, and the costs required.

It is important to understand how investments can improve the confidence in the performance of the disposal system. Investments in the natural system can only change our understanding of the earth. Thus, investments in field characterization will support the development and validation of models, the reduction of uncertainty in those models, and the reduction of uncertainty in the data supporting the models. Regardless of the size of the investment, however, we cannot change the characteristics of earth.

Investments in the engineered system can yield both improved performance, and reductions in the uncertainty of performance. This yield has a diminishing return, however, when we are attempting to assert the performance of engineered systems over periods of time which exceed our conventional engineering experience.

A term which is widely used at present is "performance allocation", which refers to the assignment of required levels of performance to the components of the disposal system. However, performance allocation must include consideration of the costs and schedules implied by the assignment of performance requirements. If fully implemented, performance allocation is the outcome of the investment decisions which must be made in the planning process.

The investment decision-making process for site characterization should conclude with the identification of models to be modified or developed, designs to be modified or developed, and data to be acquired. Once these are identified, it is necessary to develop specific plans, and to implement them. It is essential, however, that contingency plans also be developed, as well as the trigger points for activation of the contingency plans. These should be developed following the identification of all assumptions which are contained within the strategies for characterization. For example, a prime strategy for waste package development may be to construct a corrosion resistant container. This strategy assumes that such a container can be developed, meeting the performance requirements, at an acceptable price, and within an acceptable period of time. Given that these assumptions may not be valid, a contingency strategy should be developed. Such a strategy might be to develop a package which incorporates sorptive materials, thus addressing the Nuclear Regulatory Commission's package containment requirement by confining nuclides within the sorptive material and not within a container.

PROCESS ITERATION

This entire planning process must be an ongoing process. As new data are acquired, new models are developed and new designs are developed, the baseline for the site changes. These changes may invalidate some portion of the investment decisions previously made. Equally, baseline cost and schedule changes may invalidate the investment decisions. Thus, it is essential that the strategies for characterization and repository development be continually evaluated, and that the program retain flexibility to change to meet the overall objectives.

SUMMARY

The principal points of this paper are summarized below.

Objectives: Site characterization is not merely an activity to acquire field data. It is an activity to develop a suitable disposal system. Site characterization must have as its foundations (1) a clear understanding of the nature of the disposal system; (2) a clear understanding of the inherent uncertainties in the performance of the disposal system; and (3) cognizance of the time and fiscal limits.

Performance Requirements: Site characterization must be founded upon a clear understanding of the deterministic and probabilistic nature of all disposal system performance requirements.

Strategy Development: Site characterization must be undertaken applying investment strategies. There are specific and quantitative objectives which the system must attain. There are many individual strategies which are possible, but only limited time and money available to fulfill the objectives. Therefore, development of strategies must focus on these strategies which will yield the requisite results, within schedule, and at an appropriate cost.

Planning Process: Site characterization planning must be founded upon sound strategies for investment and must include the development of contingency plans. The planning process must be iterative and flexible to account for new knowledge.