THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

COLLEGE OF MINES
DEPARTMENT OF MINING AND GEOLOGICAL ENGINEERING

BUILDING #12
TELEPHONE: (602) 626-1001

WM Record File ..102.1...
WM Dir. ....
WM Dep. Dir. ....
WMPI ..... WMLL .....
WMHT. H.M. WMHL .....
WMUR..... Others.......

March 14, 1983

WM Record File 101.1
WM Project WM-10
Docket No. ______
PDR ✓
LPDR ✓
Distribution: ______
(Return to WM, 623-SS)

Mr. H. J. Miller, Chief
High Level Waste Technical
Development Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Miller:

Please find enclosed a copy of the paper you expressed an interest in. Sorry, it took that long to get a hold of.

Best regards,

Jaak

Jaak J. K. Daemen

mp

encl.

00327

PERFORMANCE ALLOCATION TRACEABLE TO REGULATORY CRITERIA AS APPLIED TO SITE CHARACTERIZATION WORK AT THE BASALT WASTE ISOLATION PROJECT

R. A. Deju
H. Babad
G. K. Jacobs
M. S. Bensky
Basalt Waste Isolation Project
Rockwell Hanford Operations
Richland, Washington 99352

ABSTRACT

The Basalt Waste Isolation Project has developed a method for defining in detail the work required to demonstrate the feasibility of emplacing and providing for the safe isolation of nuclear wastes in a repository in the deep basalts at the Hanford Site near Richland, Washington. Criteria analysis allows the identification of areas of significant technical uncertainty or controversy that can be highlighted as issues. A preliminary analysis has been conducted, which, by identifying key radionuclides and allocating performance among the multiple barriers in a repository constructed in a basalt, allows the design and development testing activities at the Basalt Waste Isolation Project to be put into perspective. Application of sophisticated uncertainty analysis techniques will allow refinements in the analysis to be made and to further guide characterization and testing activities. Preliminary results suggest that a repository constructed in basalt will provide for the safe isolation of nuclear wastes in a cost-effective and reliable manner with a high degree of confidence.

INTRODUCTION

The mission of the Basalt Waste Isolation Project (BWIP) is to assess the feasibility of siting a nuclear waste repository in the basalts underlying the Hanford Site near Richland, Washington, and to develop and design the associated facilities and technologies required for the permanent isolation of radioactive waste in basalt formations should feasibility be demonstrated. To demonstrate the feasibility of a nuclear waste repository in basalt (NWRB), the results of site characterization activities and technology development must indicate that the proposed NWRB will comply with the proposed performance objectives and other proposed criteria found in 10 CFR 60[1] and the proposed release criteria found in 40 CFR 191.[2] A project of the complexity of the BWIP requires a technique for focusing work and for making decisions about work completeness with respect to regulatory and programmatic criteria to assure readiness for a possible license application.

The ability to trace the project's work directly to criteria can be coupled with a technique that allocates waste isolation performance to the geologic setting and the engineered subsystems (waste package and repository) to create a powerful decision-making tool to guide the project's characterization, development, and design activities.

This paper illustrates the applicability of criteria/work element traceability, coupled with the allocation of performance (based on U. S. Environmental Protection Agency (EPA) proposed criteria), to the design of a repository seal system and the design of a site-specific waste package for an NWRB.

CRITERIA TRACEABILITY AND WORK PLANNING

As part of the BWIP planning activities, in conjunction with the preparation of the Site Characterization Report for the BWIP,[3] the project staff has developed a method defining in detail the work required to meet applicable regulatory and programmatic criteria. The results of the criteria analysis not only provide the project with a detailed statement of work elements needed to satisfy each criterion, but also create a detailed listing of the data needed and analyses to be performed for each work element (Table I). Criteria analysis, which forms the basis for project planning, also allows the identification of areas of significant technical uncertainty or controversy that can be highlighted as "issues." The logic behind the criteria-based planning process is illustrated in Fig. 1.

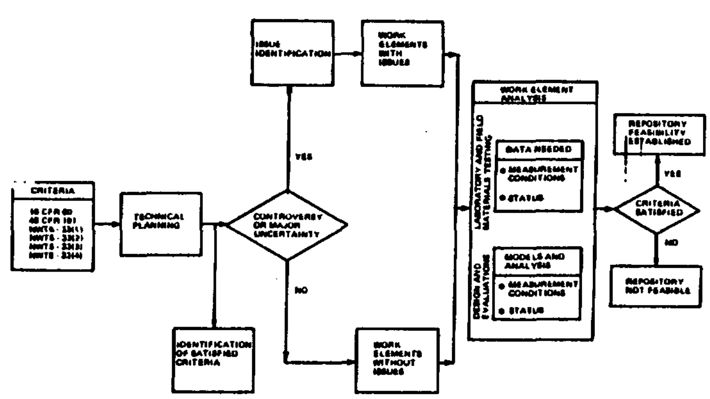


Fig. 1. Logic for Definition of Basalt Waste Isolation Project Criteria-Based Work Elements/Issues.

A summary of the multiple-step iterative process used by the BWIP to apply the principles of criteria traceability to site qualification and engineering design activities is described below:

1. Criteria analysis is used to define site characterization and engineering development (work elements and data needs) requirements (see Table I and Fig. 1).

Table I. An Illustration of Criteria Analysis: Criteria/Issues/Work Elements/Information Needs.

Technical criteria	Issues	Work element	Information needs (data and analysis)
W.1 - Design			
<u>General Requirements of Design</u> <u>(60.135(a))</u> The design of the waste package shall include the following elements: <u>Containment of Wastes</u> <u>(60.111(b)(2))</u> The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure. This requirement does not apply to transuranic waste unless transuranic waste is emplaced close enough to high-level waste that the transuranic release rate can be significantly affected by the heat generated by the high-level waste. For clarification see: NWIS 33(1), 3.4.2 NWIS 33(4), 3.1 NWIS 33(4), 3.2.1 NWIS 33(4), 4.3.2.1	W.1.A* Does the very near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance? (i.e., What is the maximum expected release rate from the engineered system, and does the geologic setting prevent the waste package containment objective from being achieved?)	W.1.1.A* Determine the maximum operating temperature limits for waste form, backfill, canister, and host rock.	Waste form dissolution in a basalt waste package environment. Backfill dehydration behavior and alteration rates at atmospheric pressure and elevated temperature in the presence and absence of water. Canister materials corrosion rates in the repository environment as a function of temperature. Thermal limitation of host rock for the reference repository configuration.
		W.1.2.A* Determine conditions that affect design of waste packages, including thermal loading, mechanical loading, and chemical environment, during handling, shipment, emplacement, retrieval, and after repository decommissioning.	Temperatures of waste package components. Mechanical loading of waste package components. Groundwater migration rates into waste package. Chemical composition: Eh and pH of groundwater in contact with the waste package components.
<u>High-Level Waste Releases</u> <u>(60.111(b)(2)(ii)(A))</u> For high-level waste, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the. . .		W.1.3.A* Determine the effect of the waste package radiation environment on near-field geochemistry, waste package, and barrier material performance.	<u>Testing in a Radiation Field</u> • Corrosion rate of canister materials • Physicochemical stability limits of backfill materials • Radiolysis products of Grande Ronde groundwaer • Dissolution mechanism and dissolution rate of waste forms.

*Identification numbers for traceability.

2. The required performance, in terms of maximum permissible release rates (waste package) and minimum traveltimes (repository seal system), of the engineered subsystems is established using performance analysis models. The allocation of performance requirements is based on the premise that a minimum performance of the natural system (the site) can be initially defined using "minimum" credible values for site parameters (radionuclide solubilities, radionuclide distribution coefficients, groundwater traveltimes, hydraulic conductivities, head differentials, etc.) that, in conjunction with regulatory criteria, provide bounding conditions for the performance of the engineered system.

3. The status of a work element is reviewed in terms of allocated performance for each repository subsystem and its component barriers. For example, does a given repository seal system design allow creation of a preferential pathway for radionuclides to the accessible environment?

4. An analysis of the degree of conservatism in the initial performance allocation is made to clearly identify those simplifying modeling or data assumptions used that may differ from those anticipated in the actual repository. Input data and modeling assumptions are evaluated to determine the statistical uncertainty of a given performance allocation. The needs for additional data (either quantity or quality), identified through uncertainty analyses or by engineering judgments, where appropriate, are incorporated into the planning process, and the materials or engineering tests or site characterization activities required to obtain the data are initiated.

5. Completion of steps 3 and 4 will identify where engineering alternatives (technology/design), aimed at correcting any performance shortfalls, need to be evaluated. Trade, design, and engineering study techniques can be utilized to obtain recommendations for cost-effective design/technology development activities.

6. Design, testing, and/or development programs for each engineered subsystem design and its component barriers are initiated.

7. The performance of engineered subsystem designs is reassessed using realistic models to determine with a high degree of confidence whether performance requirements have indeed been met by the design concepts.

The iterative process described above is continued through all phases of project activity. The relationship of the design, data acquisition, and performance assessment activities to meeting criteria is illustrated in Fig. 2. A summary of the types of test, design, and performance activities as a function of project phase and key site selection/qualification documentation is shown in Table II.

The remainder of the paper will detail the approach used by the BWIP to establish performance requirements for the engineered subsystems (waste package and repository seal system). The application of uncertainty analysis to some of the key performance parameters for an NWRB (groundwater traveltimes, radionuclide solubility and sorption controls, waste

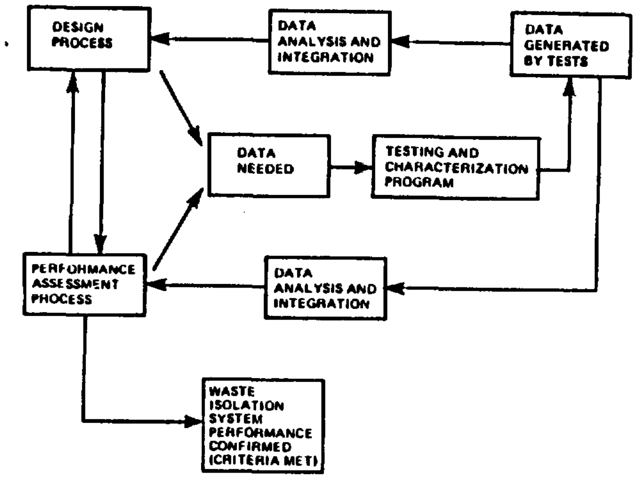


Fig. 2. Relationship of Design and Performance Assessment to Data Acquisition.

Table II. The Relationship of Qualification/ Characterization Activities to Site Selection And Documentation.

Test activities	Design	Performance	Selection and licensing	Project phase
Screen[a]	Functional and conceptual	Conceptual models/ performance allocation	Site Characterization Report	End of site screening
Select[a]	Upgraded conceptual/ preliminary	Detailed models	Site Recommendation Report	Site characterization
Detailed evaluation[b]	Preliminary	Benchmarked and verified models	Preliminary Safety Analysis Report/Environmental Impact Statement	Start of construction
Reliability determination[c]	Final	Benchmarked, verified, and validated models	Final Safety Analysis Report	Start of operation
Final verification[c]			Closure Application	Start of decommissioning

[a]Bench-scale tests.
[b]Bench-scale and engineering-scale tests.
[c]Engineering-scale and in situ tests.

package release rates, etc.) will also be addressed. A preliminary evaluation of the contribution to repository performance among the multiple barriers present in an NWRB will illustrate how performance allocation and consideration of potential uncertainties can be used to guide site characterization and engineering design and development activities.

ALLOCATION OF ENGINEERED SUBSYSTEM PERFORMANCE REQUIREMENTS

The overall performance of an NWRB may be expressed in terms of the performance of its three main subsystems:

1. the geologic setting;
2. the waste package;
3. the repository seal system.

The performance of these three subsystems, through a complementary relationship, determines the overall performance of the repository, which must, at the very least, satisfy the proposed regulatory criteria. In addition, the repository subsystems should provide multiple barriers to radionuclide releases to comply with proposed regulatory criteria and provide for the safe isolation of radioactive wastes.

The performance required of a waste isolation system can be treated as a function of the nature and performance of the individual barriers that comprise it. This concept (Fig. 3 and 4) shows schematically how the waste package, repository seal system, and site geohydrologic system will act to isolate nuclear wastes. In simple terms, the performance of a mined geologic disposal system can be conceptualized as:

$$\begin{array}{c}\text{Total mined}\\ \text{geologic}\\ \text{disposal}\\ \text{system}\\ \text{performance}\end{array} = \begin{array}{c}\text{Regulatory}\\ \text{criteria}\end{array} = \begin{array}{c}\text{(Site, waste}\\ \text{package, and}\\ \text{repository}\\ \text{seal system}\\ \text{performance)}\end{array} \quad (1)$$

$$\text{Performance} = \begin{array}{c}\text{Release to}\\ \text{accessible}\\ \text{environment}\end{array} = \begin{array}{c}\text{Waste package/}\\ \text{seal system}\\ \text{releases}\\ +\\ \text{Waste package/}\\ \text{site releases}\end{array} \quad (2)$$

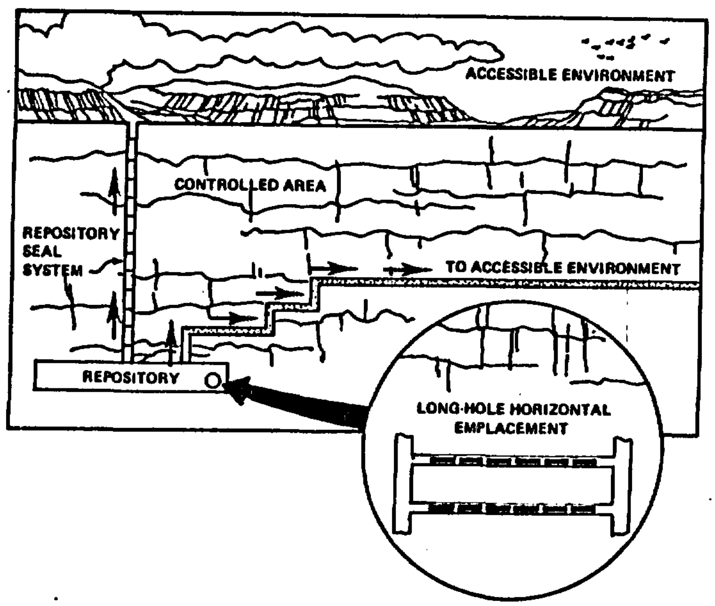


Fig. 3. Release of Radionuclides from the Engineered Subsystems.

The key to the understanding of this concept is the realization that radionuclides released from the waste package can reach the accessible environment by migration either through the host rock (site) or through the repository seals (Fig. 3 and 4).

In establishing performance requirements for the waste package, the relative importance of each pathway must be addressed. It is apparent (Fig. 4) that in determining the required performance of the seal system, the performance of the waste package is very important. For example, during the containment period (1,000 yr), with no release of radionuclides from the waste package, there are no isolation-related performance requirements for the seal system. Additionally, during the isolation period, while nuclides are slowly released from the waste package, the performance required of the seal system will depend upon the rate of release of radionuclides from the waste package. Preliminary analyses suggest that the site subsystem is the most important in evaluating repository performance. The contribution to releases at the accessible environment via the seal system path-

The bars labeled groundwater traveltime illustrate the case where the inventory is instantaneously and completely released into the groundwater. This solution is then transported to the accessible environment with no consideration of solubility or sorption controls along the pathway. The reduction of total toxicity from consideration of traveltime alone is approximately 2 to 3 orders of magnitude.[b] Further reduction of the toxicity occurs when radionuclide solubilities are allowed to control the dissolution and release of radionuclides into the groundwater and the subsequent transport to the accessible environment takes place with no consideration of sorption controls. For the expected-conservative and expected-favorable cases, these two barriers (traveltime and radionuclide solubility) act to reduce the initial inventory to acceptable levels. The results for this case illustrate the importance of understanding radionuclide solubilities, because the very conservative case, although having a low probability of occurrence, does not reduce releases nearly as much as the expected-conservative and expected-favorable cases.

Sorption control during transport to the accessible environment is the next sequential barrier added to the analysis. For all cases, the consideration of this additional barrier reduces releases to below acceptable levels. This result is significant, because with confirmation of the very conservative values for groundwater traveltime, solubilities, and sorption coefficients via the characterization and testing programs at the BWIP, high confidence will be demonstrated that an NWRB will reduce releases to the accessible environment well below acceptable levels even when credit is not taken for the multiple engineered barriers to be utilized.

The last two sets of bars (Fig. 7) illustrate the effect of two engineered barriers for the case of very conservative traveltime, solubility controls, and sorption controls.[c]

The significance of these results is twofold: (1) further reduction of releases to the accessible environment occurs when waste package containment and release rate barriers are considered and (2) the level of confidence of the overall repository system meeting all performance criteria is increased. Results such as these are used for guidance in the waste package design and development testing program. These results also reinforce the position of the BWIP that the application of the multiple barrier (natural and engineered) concept, for both likely and unlikely performance of the site, results in high confidence that an NWRB will provide for the safe isolation of nuclear waste.

---

[b]Currently proposed U.S. Environmental Protection Agency release limits specifically address only the first 10,000 yr of repository history. Expected groundwater traveltimes to the accessible environment for an NWRB are > 10,000 yr, thus providing compliance with U.S. Environmental Protection Agency proposed criteria. For conservatism and illustration purposes, subsequent 10,000-yr periods of repository history were evaluated in this analysis. When sorption controls are considered, many of the radionuclides do not reach the accessible environment for several hundred of thousands of years.

[c]For reference, the last bar (F, G, H, I, J) illustrates the case for all expected-conservative conditions.

CONCLUSIONS

This paper has described the application of criteria traceability to site characterization and design and development activities at the BWIP. As an example, the application of the methodology to some of the key processes important to the isolation performance of the repository have been discussed. These include the identification of key radionuclides, the allocation of performance to multiple barriers, and the analysis of uncertainties. Examples of these processes were presented to illustrate how they are applied at the BWIP to guide site characterization and testing programs.

The methodology described in this paper and as shown in the examples enables BWIP management to focus the resources of the project on those areas of key performance parameters.

The project uses performance-related criteria as tools to allow the timely termination of work that has achieved its goals (meaningful and cost-effective system development or enhancement). Thus, the desire of the technical staff to optimize all measurements and analyses can be refocused on those areas where improvement of the data base, development of alternative technologies, or advanced testing can demonstrate cost-beneficial enhancement of system or subsystem performance.

REFERENCES

1. NRC, 1981, "Nuclear Regulatory Commission, 10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories," Federal Register, Vol. 46, No. 130, July 8, 1981, Proposed Rules.

2. EPA, 1982, "Environmental Protection Agency, 40 CFR 191, Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Federal Register, Vol. 47, No. 250, December 29, 1982, Proposed Rule.

3. Rockwell, 1982, Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL 82-3, Rockwell Hanford Operations for the U.S. Department of Energy, Washington, D.C., November 1982.

4. Early, T. O., Jacobs, G. K., Drewes, D. R., and Routson, R. C., 1982, Geochemical Controls on Radionuclide Releases from a Nuclear Waste Repository in Basalt: Estimated Solubilities for Selected Elements, RHO-BW-ST-39 P, Rockwell Hanford Operations, Richland, Washington.

5. Smith, M. J., Jacobs, G. K., Bensky, M. S., and McCall, T. B., 1983, Waste Package Performance Requirements for a Repository Located in Basalt, RHO-BW-SA-275 P, Rockwell Hanford Operations, Richland, Washington.

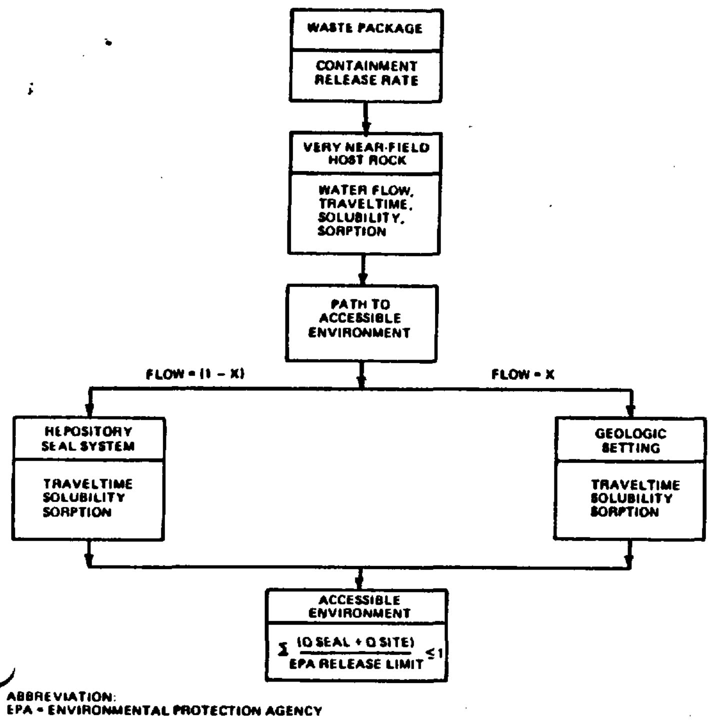


Fig. 4. The Multiple Barrier System.

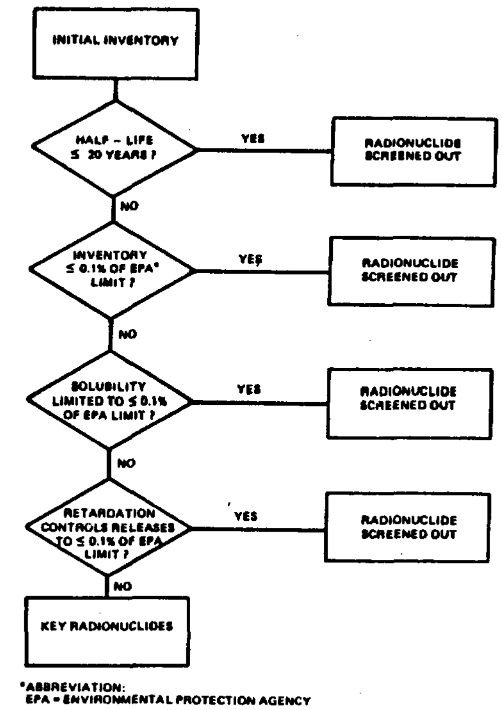


FIGURE 5. Steps to Identify Key Radionuclides.

way can be controlled with simple and cost-effective design concepts. The waste package containment can also be accomplished with a simple system. However, inasmuch as the waste package provides the initial source of nuclides and controls their release, the synergism between the site and the waste package must be understood. Therefore, the remainder of the discussion on performance allocation in this paper will specifically address the waste package/site subsystems.

IDENTIFICATION OF KEY RADIONUCLIDES

To put waste package performance and, therefore, guide the design and testing activities into perspective, the BWIP has carried out a preliminary allocation of performance requirements for the engineered subsystems, based primarily on data reported.[3] A detailed description of the methodology and results as applied to the waste package subsystem has been reported.[4] The following paragraphs provide the reader with an overview of the performance allocation methodology, which will serve to put the process into perspective, and demonstrate its ability to define data requirements.

The first step in conducting any performance analysis is to identify those radionuclides that, because of their inherent characteristics, will have significant impact on the performance of the repository. The results of such a screening process should then be confirmed with more sophisticated models of repository performance. Four screening criteria were used to reduce the total number of radionuclides in the inventory to those that were key to the overall performance of the NWRB (Fig. 5). The half-life criteria are consistent with U.S. Environmental Protection Agency proposed criteria, which conclude that, with disposal in mined geologic repositories, radionuclides with half-lives of < 20 yr will decay to insignificant levels rapidly enough so as to not require special attention for long-term isolation. Radionuclides with initial inventories (fission products) or maximum inventories (decay-chain daughter products) significantly less than U.S. Environmental Protection Agency proposed release limits at the accessible environment have no impact on repository performance because they are not present in hazardous quantities. Radionuclides that have solubilities[a] low enough to control releases from the repository significantly below U.S. Environmental Protection Agency proposed release limits at the accessible environment have no impact on repository performance because potential releases from the repository are not of hazardous quantities. Radionuclides with sufficient sorption[a] during transport so that releases to the accessible environment are significantly below U.S. Environmental Protection Agency proposed release limits do not impact repository performance. The results of radionuclide screening have led to the identification of a small number of key radionuclides for which testing is required. It should be noted that from a chemical point of view only a single isotope of each element needs testing, since isotopic effects on geochemical factors for the nuclides of concern will be very small. The uncertainties in our present data base on radionuclide sorption and/or solubility have led to the distribution of radioelements found in Table III. The distribution of elements (Table III) can be rationalized as follows. First, the solubility data used in the screening process were calculated, using available thermodynamic data, for site-specific conditions expected for an NWRB.[5] Such information must be confirmed by testing under actual repository conditions. For those species that have solubilities that appear to be significantly lower than the screening criterion, only confirmatory tests are required. The remaining elements must be evaluated in a detailed manner to determine whether a waste package must be designed to limit their release. Second, the sorption data used in the screening process are for the most part, based on experimental data obtained under repository conditions. However, where

[a]Values used in the screening process require confirmation via site-specific testing (Table III).

Table III. An Example of Selected Geochemical Data Required to Confirm Preliminary Performance Allocations for Those Radioelements Not Screened by Half-Life or Inventory Considerations.

Degree of concern	Solubility tests	Sorption tests	Comments
Elements not requiring specific testing	Cesium, strontium, radium, lead, americium, thorium, tin	Cesium, strontium, radium, lead, americium, thorium, tin	Radioisotopes of these elements have no impact on repository performance, based on current understanding of either solubility or sorption controls. AND High degree of confidence in current understanding of solubility or sorption controls.
Elements requiring confirmatory tests only	Uranium, plutonium, neptunium, nickel, zirconium	Uranium, plutonium, neptunium, nickel, zirconium	Radioisotopes of these elements have no impact on repository performance, based on current understanding of either solubility or sorption controls. AND Moderate confidence in current understanding of solubility or sorption controls.
Elements requiring detailed testing	Carbon, selenium, iodine, technetium	Carbon, selenium, iodine, technetium	Radioisotopes of these elements impact repository performance, based on current understanding of either solubility or sorption controls. OR Radioisotopes of these elements do not impact repository performance, but low confidence in current understanding of solubility or sorption controls.

there are insufficient data or where questions remain about the behavior of certain elements, further confirmatory or detailed testing is required. The priorities in the BWIP geochemistry test program, as a result of this analysis, are to evaluate in detail the sorption and/or solubility behavior of those key radionuclides identified that may be able to reach the accessible environment as a result of migration in groundwater.

To determine how well a waste package should perform (i.e., to allocate waste package performance requirements), a number of additional variables must be considered. A waste package can control releases of radionuclides either by containing them for a determined period (primarily the function of the canister) or by controlling releases from the waste package to the repository/site subsystems (a function of the waste form, canister failure mode, and backfill). The degree to which containment or controlled release is required is a direct function of the performance characteristics of the site subsystem. The movement of radionuclides from the engineered subsystems to the accessible environment will depend in part upon the amount of time it takes groundwater to travel to the accessible environment, as well as the geochemical characteristics along the flow path. It is important to identify and quantify uncertainties in the traveltime and geochemical characteristics of the site subsystem.

UNCERTAINTY ANALYSIS

Initial studies to allocate performance requirements to the components of engineered systems used engineering judgment to analyze the input data obtained from screening studies or from the literature. Successive iterations of the performance assessment process, utilizing an expanded data base resulting from site characterization, materials and other engineering testing and design activities, are being statistically analyzed to identify the uncertainty in the data base. This is coupled with a parallel analysis that aims at determining the uncertainty in the predicted repository performance.

Any uncertainty analysis must provide a rigorous means of quantifying the confidence in long-term predictions of repository performance. Uncertainty in predictions of performance arises basically from two causes: (1) inaccuracies in the mathematical and numerical models used to represent a system or process and (2) incomplete knowledge of the data and boundary or initial conditions required by that model. Confidence in the numerical models, and to some extent the mathematical models, is established by the benchmarking and verification of the computer codes used for predictive modeling. However, the uncertainty in input data and boundary or initial conditions is more significant. For all practical purposes, some residual uncertainty will always be present in model input parameters. This uncertainty is recognized by the regulatory agencies in their requirement that an applicant for a license to construct, operate, and subsequently decommission a repository provide reasonable assurance of the performance of the system.

Currently U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency proposed regulations contain two broad performance measures that a repository must comply with: (1) a 1,000-yr preemplacement groundwater traveltime to the accessible environment and (2) cumulative release limits across a boundary 10 km from the repository. Additional requirements for the containment of wastes for 1,000 yr and an inventory-related release rate (10^{-5} parts/yr) from the engineered system complete the U.S. Nuclear Regulatory Commission draft performance objectives. Predictive modeling to date, including the studies to allocate subsystem performformance, indicate that an NWRB will meet these performance criteria when mean values of input parameters, boundary, and/or initial conditions are used in the performance models.

Efforts are now under way within the BWIP to assess the degree of confidence, by means of uncertainty analyses, that can be placed on such model predictions. Initial project emphasis, because of the existence of a large data base from site characterization activities, is on the estimation of uncertainty of preemplacement groundwater traveltimes. Monte Carlo techniques, in conjunction with a finite-element numerical model, are being used to assess the uncertainty in estimates of preemplacement groundwater traveltimes to the accessible environment. The key input parameters to this analysis are transmissivity and effective thickness (i.e., the product of effective porosity and formation thickness). Present analyses only treat transmissivity as a stochastic variable because of a general lack of site-specific effective thickness data. If necessary, boundary conditions in the model can also be treated stochastically. Results will be presented in the form of cumulative probability plots (Fig. 6), which will allow the probability of compliance to current regulatory standards to be determined.

Determining the uncertainty in the prediction of radionuclide mass flux across the 10-km boundary is a more complex problem because it involves the analysis of non-steady-state coupled groundwater and heat flow, as well as estimation of the uncertainty

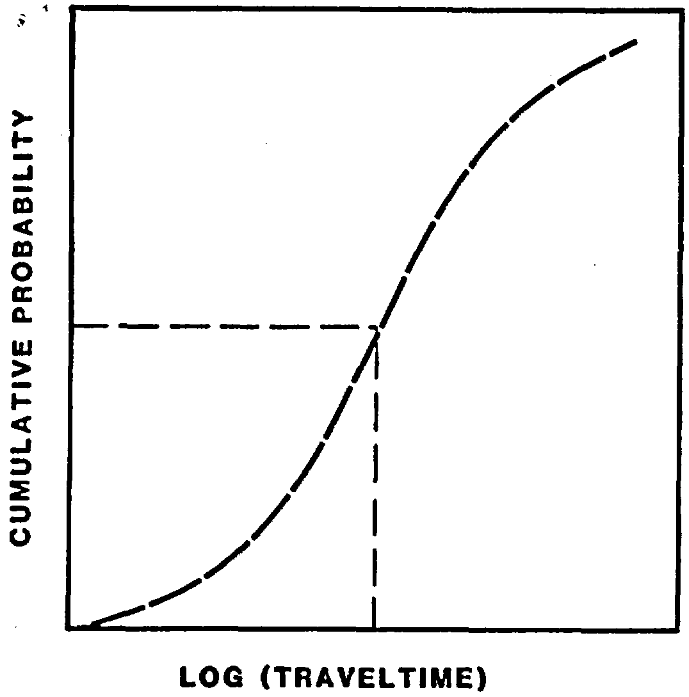


Fig. 6. An Illustration of a Cumulative Probability Plot of Preemplacement Groundwater Traveltimes.

associated with the key geochemical parameters of radionuclide steady-state solution concentration/ solubility limits and sorption coefficients. Current BWIP efforts are being directed at determining the most suitable means of addressing this problem. Methods being considered are Monte Carlo, finite-order, and stochastic Lagrangian techniques.

The results of the determination of uncertainty will provide the project with information that will define the probability that any allocation or assessment of performance will result in meeting or bettering regulatory criteria or performance objectives. Such treatment allows the BWIP to statistically describe performance, enabling the staff to build the required (technically conservative) safety margins into design of the engineered subsystems.

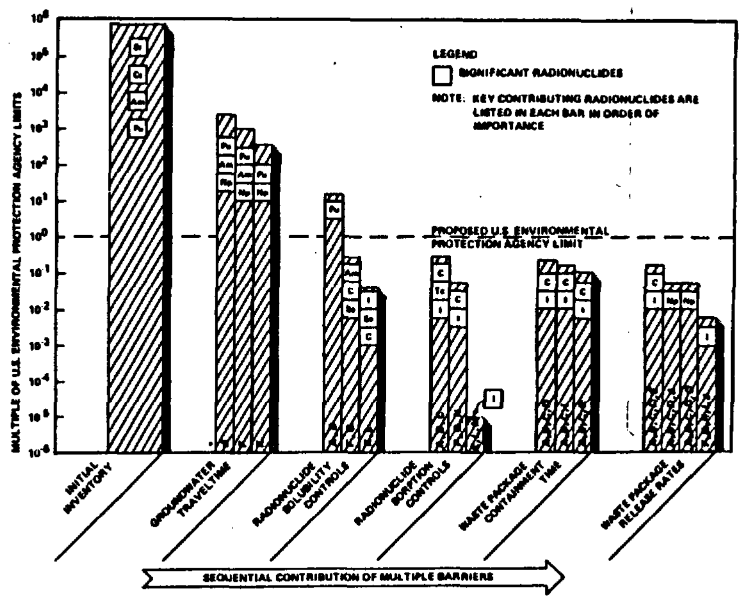
PRELIMINARY ALLOCATION RESULTS

The purpose of the allocation analysis presented here is to illustrate how the individual barriers of the multiple barrier concept contribute to the overall performance of the repository system. The individual barriers analyzed include:

1. groundwater traveltime to the accessible environment;
2. radionuclide solubility controls;
3. radionuclide sorption controls;
4. waste package containment time;
5. waste package release rates.

The contribution of each barrier to reducing the initial radionuclide inventory to acceptable levels reaching the accessible environment is evaluated sequentially. Additionally, preliminary estimates of the uncertainty associated with each barrier have been made. It is anticipated that the range from very conservative to expected-conservative to expected-favorable conditions illustrated represents an uncertainty band that will encompass actual uncertainties for each barrier when they are established. Therefore, there is a high probability that results from future performance allocations will fall within the band of results presented here for this one case. This preliminary allocation illustrates how the relative importance to performance of each barrier can be defined and used to guide the site characterization and design and development testing programs.

The results from a simplified performance allocation analysis are illustrated in Fig. 7. The initial inventory bar presents the total toxicity, relative to U.S. Environmental Protection Agency proposed release limits at the accessible environment, present in a repository inventory of one half spent fuel and one half commercial high-level waste. The initial inventory exceeds the U.S. Environmental Protection Agency proposed limits by a factor of nearly 10^6. The subsequent bars (Fig. 7) illustrate how the multiple barriers present in an NWRB reduce this factor of 10^6 to an acceptable level well below the U.S. Environmental Protection Agency proposed limits.



EXPLANATION OF LETTER SYMBOLS

	GROUNDWATER TRAVELTIME	RADIONUCLIDE SOLUBILITY LIMITS	RADIONUCLIDE SORPTION CONTROLS	WASTE PACKAGE CONTAINMENT TIME	WASTE PACKAGE RELEASE RATE
VERY CONSERVATIVE	A = 20,000 YEARS	B = VERY CONSERVATIVE SOLUBILITY	C = VERY CONSERVATIVE SORPTION	D = 1,000 YEARS	E = 10^{-4} YEAR^{-1}
EXPECTED CONSERVATIVE VALUES	F = 44,000 YEARS	G = EXPECTED CONSERVATIVE SOLUBILITIES	H = EXPECTED CONSERVATIVE SORPTION	I = 5,000 YEARS	J = 10^{-5} YEAR^{-1}
EXPECTED FAVORABLE VALUES	K = 80,000 YEARS	L = EXPECTED FAVORABLE SOLUBILITIES	M = EXPECTED FAVORABLE SORPTION	N = 8,000 YEARS	O = 10^{-6} YEAR^{-1}

Fig. 7. Sequential Contribution of Multiple Barriers for the First 10,000-Year Period and Subsequent Time Periods. Bar A, B, C, D illustrates releases when very conservative groundwater traveltimes, very conservative solubility controls, very conservative sorption controls, and expected-conservative waste package containment times are considered. Bar A, B, C, D, O is the same as bar A,B,C,D, except that a radionuclide release rate of 10^{-6} parts/yr from the waste package is also considered.