Sandia National Laboratories
Albuquerque, New Mexico 87185

April 9, 1985

Mr. Marc Rhodes
Repository Projects Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Dear Mr. Rhodes:

Enclosed is the summary of activities during March 1985 for the following tasks (A-1165): (I) Assisting in the Development of the Licensing Assessment Methodology (II) Monitor and Review Aspects of DOE programs; (III) Identifying Techniques for Probability Assignments; and (IV) Short Term Technical Assistance.

Sincerely,

Robert M. Cranwell

Robert M. Cranwell, Supervisor
Waste Management Systems
Division 6431

RMC:6431:jm

Enclosure

Copy to:
Office of the Director, NMSS
Attn: Program Support
Robert Browning, Director
Division of Waste Management
Hubert Miller
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Malcolm R. Knapp
Division of Waste Management
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Health Siting & Waste Management Division
John Randall
Division of Radiation Programs and
Earth Sciences
6430 N. R. Ortiz
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PROGRAM:	Licensing-methodology Assistance	FIN#: A-1165 Task I
CONTRACTOR:	Sandia National Laboratories	BUDGET PERIOD: 10/84-9/85
NMSS PROGRAM MANAGER:	M. J. Rhodes	BUDGET AMOUNT: $150K
CONTRACT PROGRAM MANAGER:	R. M. Cranwell	FTS PHONE: 844-8368
PRINCIPAL INVESTIGATORS:	R. L. Hunter	FTS PHONE: 846-6337

PROJECT OBJECTIVES

To assist in the overall development and integration of the licensing assessment methodology.

ACTIVITIES DURING MARCH 1985

We have begun the review and summary of five Sandia documents on far-field performance assessment methodology. Some of these documents are applications of the methodology, not contributions to it, and will probably not be included in the final integration report. We received the final Golder Task 5 report and will compare it with the draft reviewed earlier.

We are continuing the preparation of the overview document that will describe the overall licensing assessment methodology (LAM) and its relationship to the licensing issues. The overview document will briefly discuss what components of the LAM are necessary, which of these have been completed and which are under development, and what codes are currently under consideration for use in consequence analysis.

A summary of this overview document (attached) will be presented at the ANS meeting in Boston and the topical meeting on waste management in Pasco. The summary is in Sandia review and is submitted here for NRC review. Review comments must be received by May 15 in order to be incorporated.

PROGRAM:	Monitor/Review Aspects of DOE & other National and International Waste Management Programs	FIN#:	A-1165 Task II
CONTRACTOR:	Sandia National Laboratories	BUDGET PERIOD:	10/84-9/85
NMSS PROGRAM MANAGER:	M. J. Rhodes	BUDGET AMOUNT:	$86K
CONTRACT PROGRAM MANAGER:	R. M. Cranwell	FTS PHONE:	844-8368
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PROJECT OBJECTIVES

To monitor and review the performance assessment aspects of DOE and other national and international waste management programs.

ACTIVITIES DURING MARCH 1985

We completed our assistance in the preparation of EA review comments. P. A. Davis reviewed the final detailed and major comments. Major comments for the performance assessment section were formulated for all but the Nevada Site EA. Detailed comments for Richton, Vacherie, and Cypress Dome and the basalt site were written, reviewed, and re-written. In addition, P. A. Davis reviewed the NRC's comment on ground-water travel time for BWIP. Mr. Davis' comments are attached.

TO: Matthew Gordon

FROM: Paul Davis

SUBJECT: Review of the NRC comments on the hydrology section of the BWIP EA.

My major concerns have to do with the appropriateness of performing an NRC analysis of the ground-water travel time in a review and the validity of doing a stochastic analysis with insufficient information. Additional comments have been written on the copy of your comments included with this letter.

Although I also succumbed to the temptation, I now believe the EA review is not an appropriate place for an independent analysis. The problem is that the NRC analysis detracts from the very important criticisms that the NRC has of the DOE analysis. That is, the most important point the NRC can make is that ranges of data and approaches to modeling used by the DOE are not consistent with all available information. By including the NRC analysis one is left with the impression that anyone can chose the data they wish and arrive at any answer they want. This could lead to the feeling that the DOE analysis is just as valid as the NRC analysis. However, I believe the point you are trying to make is that the DOE has selected inappropriate data for their analysis. This point is already made in the detailed comments and deserves reiteration in this major comment. Possibly the most appropriate place for your travel-time analysis is in a letter report such as the item 4 you forwarded to me. In this way you could mention the results of your calculations, thereby indicating that other results are possible, and not dilute any of your other very important criticisms of the DOE travel-time calculations.

With respect to the travel-time analysis, I have difficulty accepting either the DOE or the NRC analyses. I agree with the NRC criticism of the DOE analyses, especially with respect to the ranges and assumed distributions of variables. In addition to these, I believe the DOE analyses have two major drawbacks. For one, the range of correlation of transmissivities is not obtained from site data. This range has a significant effect on results and can not be based on an assumption. My second concern is that the input and output of their stochastic modeling is not conditioned by the measured parameters. That is, in their sampling of transmissivities, the model should use field values in elements for which such measurements exist. As far as I can tell it does not. In addition, the simulated hydraulic heads are not conditioned on the measured hydraulic heads. This was essentially noticed by the NRC in the comment about the damming effect of certain combinations of transmissivities. If the stochastic simulations were conditioned on measured heads, one would not expect to get potentiometric surfaces which indicated such unrealistic conditions.

The NRC analysis also has to rely on assumed distributions and correlations. These assump[illegible]ns significantly affect th[illegible] results and should be avoided. One possible way is utilize a sampling technique and only sample from the measured values. In the case of effective thickness' at BWIP only one value would be used in all analyses. As this is the only reliable value, I believe this would be appropriate.

In another light, we performed an independent check of your travel-time analysis. This was done by utilizing your ranges and assumed distributions in Latin Hypercube Sampling and then performing a simple calculation of the travel time. Calculations were performed with and without your assumed correlations. The results are presented in the form of probability distributions and are included herein. Considering the small sample size of 25, these results basically agree with your calculations.

Finally, if you decide to keep you travel time analysis in the EA review, you should consider including additional emphasis on the significance to the finding in the EA.

PROGRAM:	Probability Techniques	FIN#:	A-1165 Task III
CONTRACTOR:	Sandia National Laboratories	BUDGET PERIOD:	10/84-9/85
NMSS PROGRAM MANAGER:	M. J. Rhodes	BUDGET AMOUNT:	$202K
CONTRACT PROGRAM MANAGER:	R. M. Cranwell	FTS PHONE:	844-8368
PRINCIPAL INVESTIGATORS:	R. L. Hunter	FTS PHONE:	846-6337

PROJECT OBJECTIVES

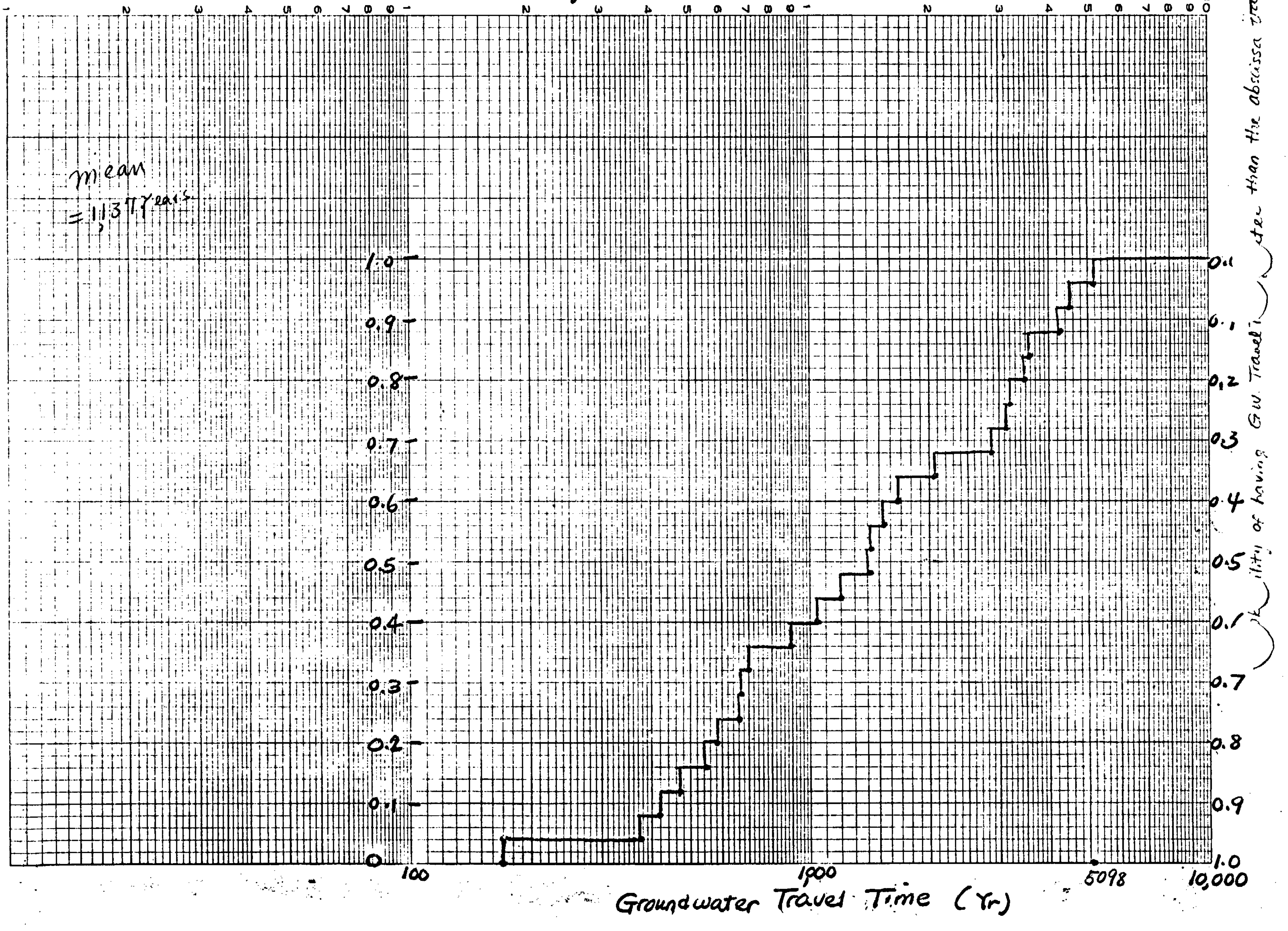
To identify techniques for assigning probabilities to geologic processes and events.

ACTIVITIES DURING MARCH 1985

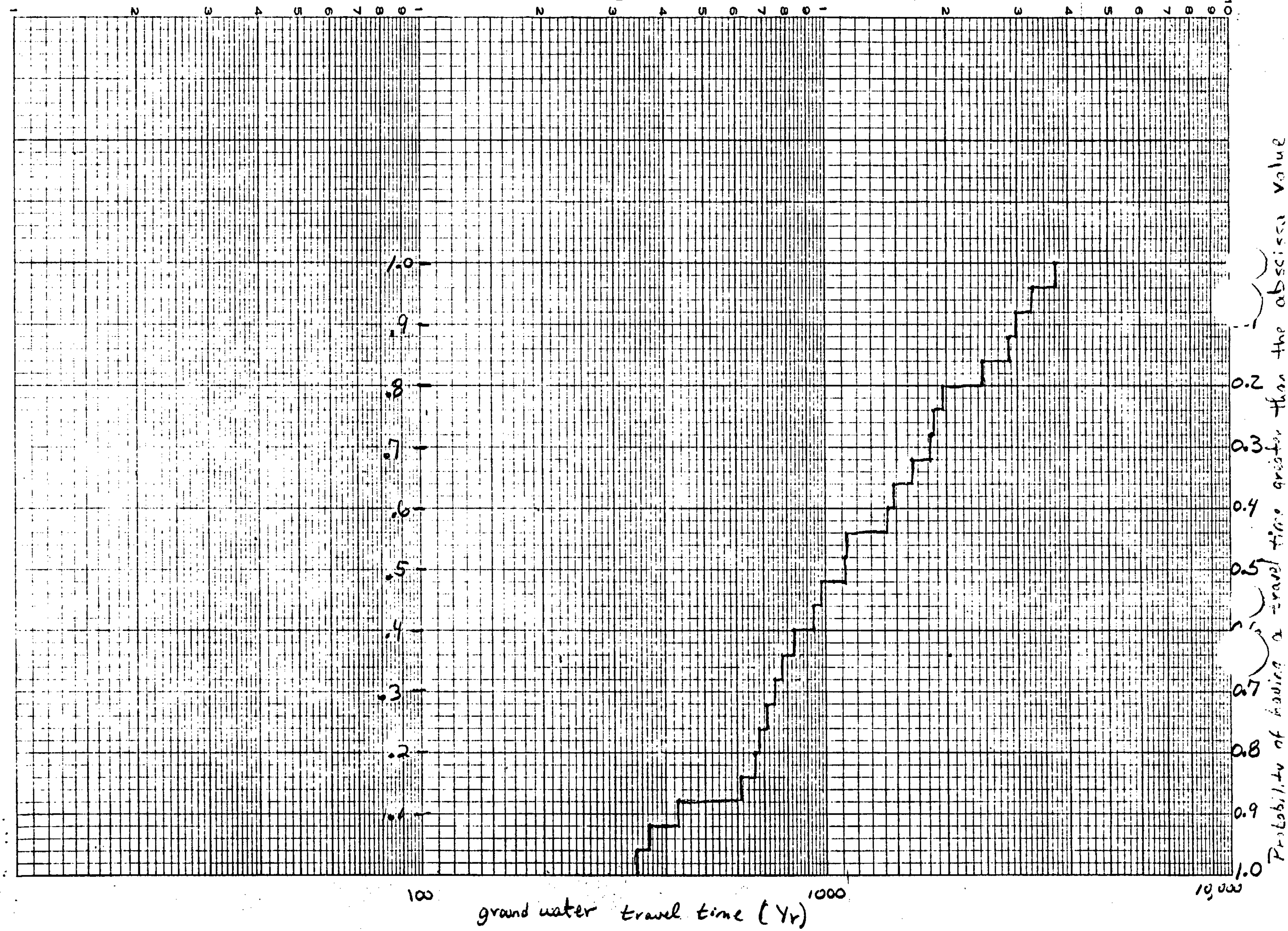
We received word of NRC's choices of expert panelists from L. A. Peeters by telephone in late March. We confirmed by telephone that all but one of the chosen experts is still available. In early April, we expect to find a substitute for the unavailable expert (Neville Cooke) and begin placing contracts. Placing the contracts will probably take six to eight weeks.

A paper describing the proposed work in probability has been written for the topical meeting in Pasco. It is submitted here for NRC review. Comments must by received by May 15.

LHS Analysis without correlations



LHS Analysis with correlations



PROGRAM:	Short-Term Technical Assistance	FIN#:	A-1165 Task IV
CONTRACTOR:	Sandia National Laboratories	BUDGET PERIOD:	10/84-9/85
NMSS PROGRAM MANAGER:	M. J. Rhodes	BUDGET AMOUNT:	$50K
CONTRACT PROGRAM MANAGER:	R. M. Cranwell	FTS PHONE:	844-8368
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PROJECT OBJECTIVES

To monitor and review the performance assessment aspects of DOE and other national and international waste management programs.

ACTIVITIES DURING MARCH 1985

No activity.

DETERMINING PROBABILITIES OF GEOLOGIC EVENTS AND PROCESSES

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ABSTRACT

The Environmental Protection Agency has recently published a probilistic standard for releases of high-level radioactive waste from a mined geologic repository. The standard sets limits for contaminant releases with more than one chance in 100 of occurring within 10,000 years, and less strict limits for releases of lower probability. The standard offers no methods for determining probabilities of geologic events and processes, and no consensus exists in the waste-management community on how to do this. Sandia National Laboratories is developing a general method for determining probabilities of a given set of geologic events and processes. In addition, we will develop a repeatable method for dealing with events and processes whose probability cannot be determined.

I. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has recently published a proposed environmental standard for the management and disposal of high-level radioactive waste.[1] The standard is probabilistic. It sets certain limits for contaminant releases that are estimated to have more than one chance in 100 of occurring within 10,000 years, and a less strict set of limits for releases estimated to have between one chance in 100 and one chance in 10,000 of occurring within 10,000 years. No limits are set for releases of lesser probability. The proposed standard requires performance assessments that estimate probabilities of events and processes that might lead to releases of radioactive waste, but it does not offer any guidelines for methods of determining probabilities.

No consensus exists in the waste-management community as to how probabilities of geologic events and processes should be determined. Methods used in the past have differed widely. In some cases, events and processes have been chosen for preliminary performance assessments without any published consideration of probabilities.[2] Some workers have assumed probabilities.[3] Some probabilities have been calculated based on fairly sophisticated mathematical techniques, but using limited or uncertain data.[4,5,6] Other studies have used a combination of these methods, depending on the availability of data.[7] The general geological literature also contains examples of probabilistic analysis of geological events and processes that are based on a variety of techniques.[8,9,10,11,12,13]

Sandia National Laboratories in Albuquerque, under the sponsorship of the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Material Safeguards and Safety, is developing a general method that can be used to determine probabilities for a given set of geological events and processes considered to be potentially hazardous. Our approach is to model probability determinations in a completely general fashion for all possible geologic conditions, emphasizing events and processes that are thought to be likely at sites the Department of Energy (DOE) is currently considering.

II. PROPOSED METHOD

Most geologic events and processes can be sorted into one of three groups when attempting to assign probabilities of future occurrence. These groups are those for which probabilities of events and processes can be determined with near certainty, fairly accurately, or only with limited confidence. In the past, however, workers have often assumed some probability, either small or large, for events or processes whose probability could be fairly accurately determined from available data. A flow chart (Figure 1) offers a systematic, repeatable method of determining whether the probability of a given event or process can be estimated with confidence.

First, some events or processes can be predicted with near certainty because our knowledge of them and the conditions under which they occur is excellent. Many of these events or processes are virtually deterministic, both because the area of concern is well understood and because quantitative development of the subject is well established on either theoretical or empirical grounds. One example of such events or processes is ground-water flow within some aquifers and basins. The physics of fluid flow through porous media is well established theoretically;[14,15] numerous quantitative models have been developed and applied to real geologic situations to predict ground-water movement; and hydrologists generally agree that several established methods and techniques provide acceptably similar results.[16] Generally speaking, ground-water data from sites currently being considered by DOE are sparse. If we assume that a DOE site is located in a basin in which porous flow dominates, then an appropriate path through the flow chart (Figure 2) implies that ground-water flow will be well understood after appropriate data are collected and ground-water flow is modeled.

Second, other phenomena can be predicted reasonably accurately today because adequate data bases exist or may be easily obtained to estimate the probability of certain geologic events and processes. Some phenomena can be predicted based on general geologic knowledge to be nearly certain to

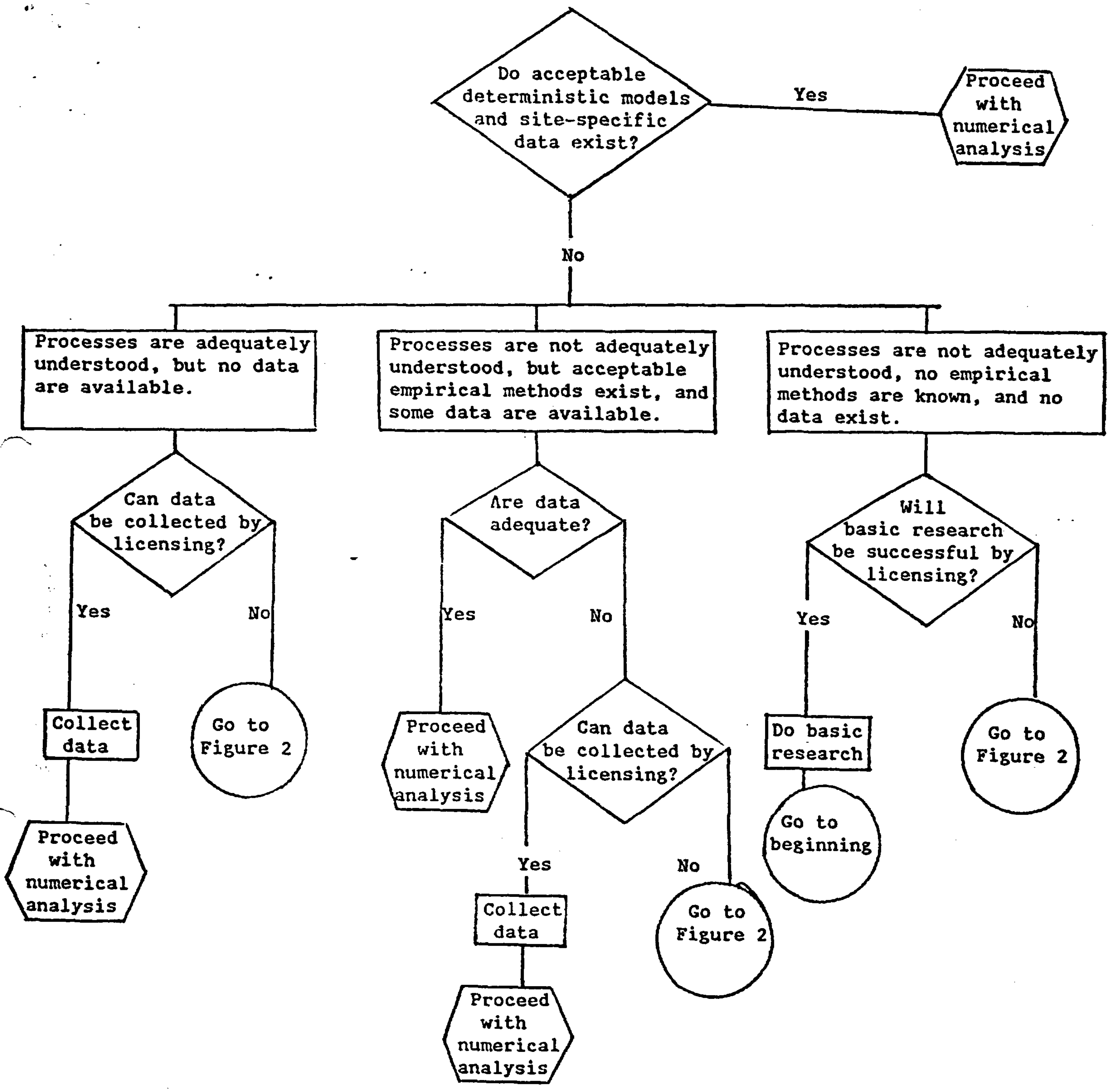

Figure 1. Tentative flowchart for sorting geologic events and processes during the application of the method for determining probabilities.

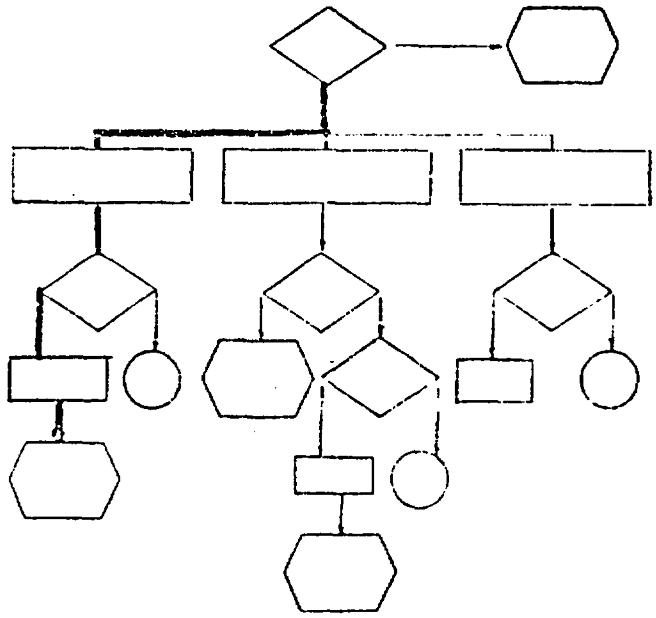

Figure 2. A path likely to be followed in assessing risk from ground-water flow in a drainage basin with few existing hydrologic data.

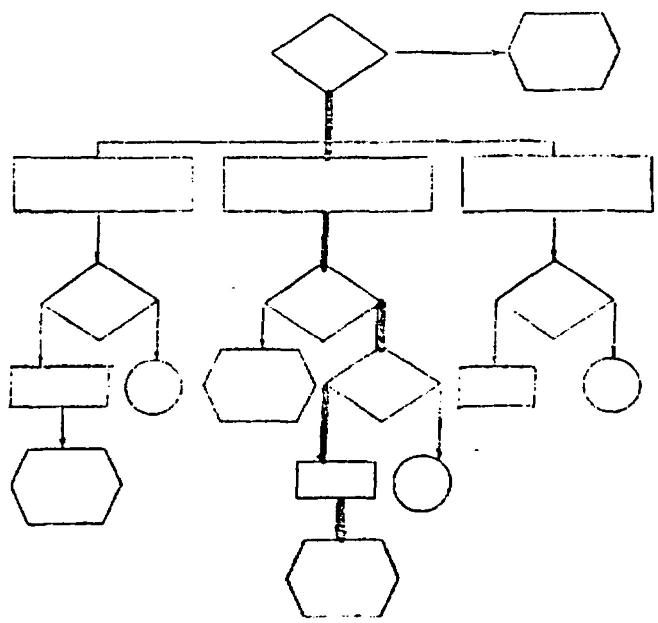

Figure 3. A path likly to be followed in assessing risk from volcanism in an area of inadequate existing data on volcanic history.

occur in a given area during a long enough period of time. For example, Quaternary volcanism is entirely restricted to the western United States, where an upper lithospheric plate is above a subducting plate margin. Here active volcanoes exist today.[17] Their frequencies of eruption during Quaternary time are generally well known (NOAA Data Center) from geologic data. Some sites being considered, such as the basalt, tuff, and Paradox Basin sites, are well inside this area of Quaternary volcanism. Because young volcanoes tend to be easily identified in the arid West, existing data are usually adequate. An appropriate path for determining probabilities of volcanism would likely involve more probabilistic analyses than did ground-water flow (Figure 3). Even though it is not possible to predict deterministically when or where a volcano will erupt next, the process is well enough understood that it can be stated that some will occur in the West. Moreover, enough data exist to determine the past rate of new eruptions in the West, and therefore (assuming that the rate continues unchanged), the probability of new eruptions. In fact, just such a calculation has been made for the tuff site in southern Nevada;[6] the probability of new eruptive vents was estimated from the known number of volcanoes and their frequency of eruption. Because the Gulf Coast salt domes being considered for nuclear waste disposal are well outside the area of Quaternary volcanism, volcanism probably need not be considered in salt dome performance assessments.

Frequencies of earthquakes and fault movements of various magnitudes are also predictable for various regional geologic settings. These predictions rely heavily upon established, extensive computer data bases such as that at the Earthquake Data and Information Center, NOAA, Boulder, Colorado, which has recorded seismic activity, measured magnitudes, and accurate geographical locations for all events recorded during the last 200 years in North America. In addition, written historical records extend these data back as much as 4,000 years for some areas of the world. Not only can accurate probabilities of frequencies of earth movements be obtained for specific locations, but accurate probabilities of ground accelerations can often be predicted. Such calculations have been made for southern Nevada.[18]

Extreme values of some geologic parameters may be difficult to predict with great accuracy even when the parameters are well understood and available data are excellent. For example, even though we may be able to accurately predict magnitudes and locations of normal seismic activity, based on recent seismic events, we may be uncertain that future events will not exceed some stated level of energy release. Seismologists have used Gimbel's theory of extreme values,[19] Markovian models,[20] and maximum entropy,[21] as well as assuming various probability distributions to estimate maxima that may be expected for future extreme values. However, we have little experience by which to judge adequacy or inadequacy of any of these methods in prediction of extreme values for geological phenomena. The most recent draft of the EPA standard[22] suggests that it may be acceptable to provide only best estimates of probability; however, uncertainty in calculations of probability should not be ignored.

Phenomena that fall into a third and final category, however, present major difficulty because they can be predicted only poorly and with limited confidence, either because the event or process is inadequately understood or because data are inadequate to make accurate predictions. Geologic events and processes that are included in this third category of poorly predictable phenomena offer the greatest uncertainties to risk evaluation in nuclear-waste disposal. A second flow chart (Figure 4) offers a preliminary method for dealing with these events and processes. The flow chart is arranged more-or-less in order of increasing uncertainty and greater undetermined risk. By following the first branch, both uncertainty and risk of a given event or process may be eliminated. For example, the unknown risks associated with raising large volumes of rock to high temperatures can be eliminated by lowering the thermal loading of the repository. Thus a design change may eliminate or reduce the probability of a risk or decrease the uncertainty associated with it.

Following the second branch (Figure 4) may result in calculation of such a low upper bound on probability that the event ceases to be of concern. The probability of new faulting that would affect the WIPP site in southeastern New Mexico has been calculated to be less than 10^{-} .[4] Even if the uncertainty is a few orders of magnitude, such a low probability removes that event from regulatory concern. Nevertheless, these estimated probabilities, even though acceptably small, retain great uncertainty and must be used cautiously.

If risk cannot be eliminated by changing the repository design, and no data that place a low bound on the probability exist, then it is appropriate to model the consequences of the event or process of concern. Some events and processes, even if assumed to have a probability of 1, have only a negligible risk because the consequences are unimportant.

If consequences are not acceptable, then it becomes important to obtain some estimate of the probability. Although it has been determined that data neither exist nor can be obtained in an reasonable amount of time that can be used in calculating or bounding a probability, expert opinion might nevertheless be useful in estimating the probability. Expert opinion should be incorporated in assessments in some probabilistic form, presumably by using Bayesion methods. If the probability is judged very low by experts, then moderate or high consequences are of small concern, although at this stage in the process, confidence in the predicted results may not be great. If, on the other hand, the probability is judged moderate or high, then risk can be calculated using the consequences determined previously and the expert judgement of the probability.

Regardless of which probability category geological events and processes fall into for purposes of establishing risk assessments for potential repository sites under consideration, all carry some measure of uncertainty which has entered into assessments at each stage of the process.

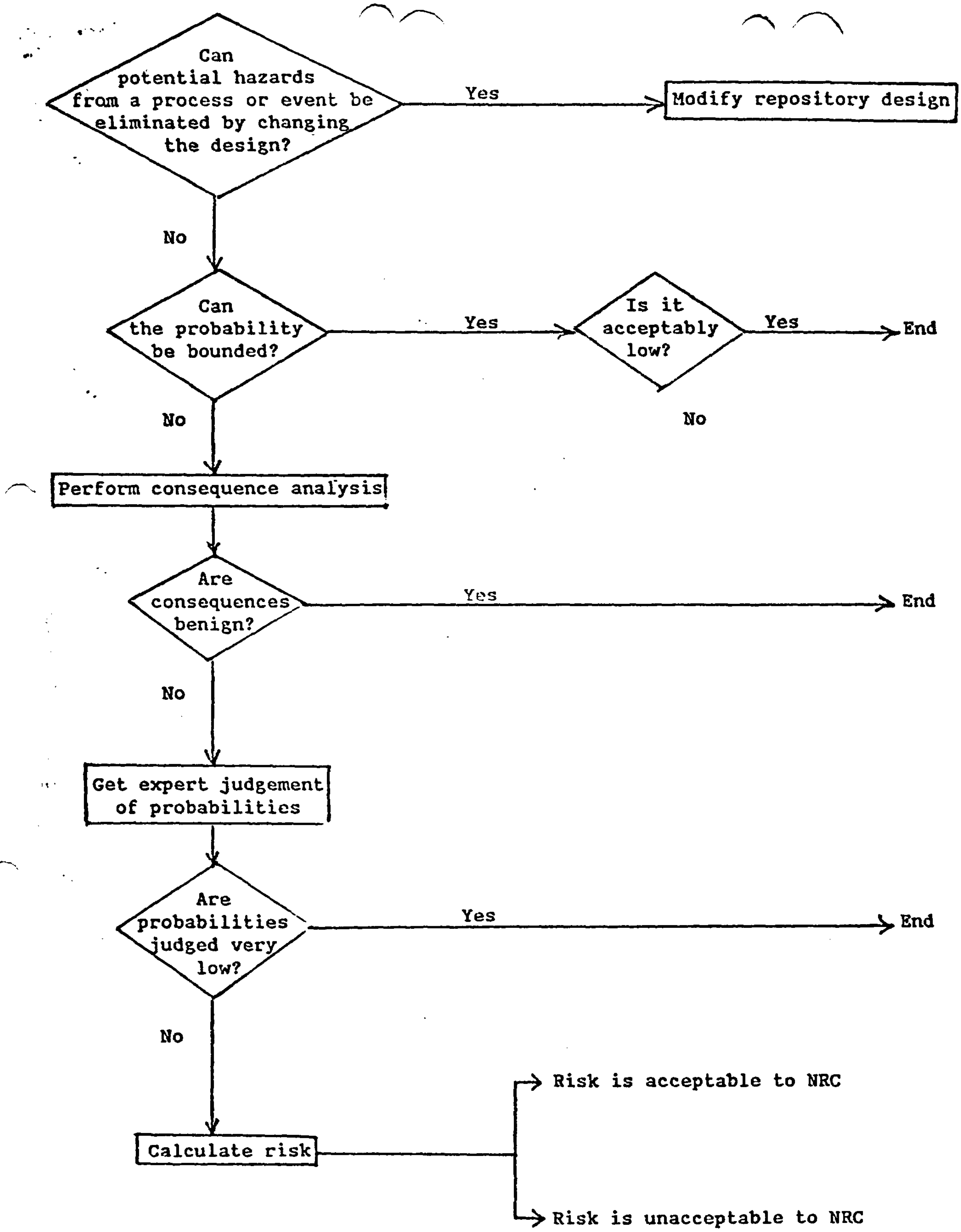

Figure 2. A flowchart for dealing with events and processes whose probabilities fall into category c.

However, in assessments of natural hazards that can be expected in the future, especially when lives of large numbers of people are involved, uncertainty estimates are mandatory. Wise decisions can be made only when accurate estimated of risks and uncertainties in these estimates are known.

If DOE does not wish to withdraw the site from consideration, then the NRC must use its regulatory discretion to determine whether or not the calculated risk is acceptable, bearing in mind the uncertainty that may be present in the expert judgement of probability.

IV. SUMMARY

Many natural events and processes that will be considered in a performance assessment can be treated deterministically or probabilistically using a systematic and repeatable method such as that outlined tentatively here. It would be useful to the waste-management community to reach some agreement on the steps to be included in establishing probabilities for risk assessment methods. In the final performance assessments, however, some expert judgement and irreducible uncertainty may be present, necessitating a final decision from the NRC on the acceptability of the residual uncertainty and risk presented by the repository.

III. REFERENCES

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DEVELOPMENT OF AN INTEGRATED LICENSING ASSESSMENT METHODOLOGY

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ABSTRACT

The U. S. Nuclear Regulatory Commission (NRC) is developing a licensing assessment methodology (LAM) for independently evaluating the Department of Energy's license applications for nuclear-waste repositories. Several NRC contractors are working separately on the LAM. A task called "integration" is examining the LAM for completeness, coherency, and redundancy, in an effort to assist the NRC in meeting its objective of ensuring that all necessary parts of the LAM are available at the time of licensing. There are four goals of the integration effort: first, to determine what analyses are required by the applicable regulations; second, to determine what components of the LAM are necessary to assess compliance with these regulations; third, to examine current NRC-funded work to determine whether necessary components are under development; and finally, as component methodologies evolve, to examine the interfaces between components. This paper reports progress on the first two goals.

I. INTRODUCTION

The U. S. Nuclear Regulatory Commission (NRC) is developing a set of tools and techniques, called a licensing assessment methodology (LAM), for use in independently evaluating the license applications to be submitted by the Department of Energy (DOE) for mined geologic nuclear-waste repositories. The NRC has a number of contractors working separately on various specific aspects of the LAM. Aerospace, Inc., is developing a method for assessing compliance of the waste package. Golder Associates has worked on aspects of the problem dealing with engineered barriers. Sandia National Laboratories in Albuquerque, New Mexico, (SNLA) is developing tools and techniques for far-field performance assessment. SNLA and GA Technologies, Inc., are developing tools for preclosure performance assessment. It has become increasingly clear that an integration effort is needed to examine the LAM as a whole for completeness, coherency, and redundancy and to suggest corrections for any flaws. The integration task is taking place at SNLA. The results from this task can be used by NRC to prioritize its allocation of funds and to guide DOE in the collection of data and design of engineered barriers.

The overall objective of the integration effort is to determine whether the NRC has or is developing all the tools and techniques that will be needed to evaluate the performance assessments contained in DOE's license applications. There are four individual goals. First, the EPA standard and NRC regulation must be examined to determine what analyses are required. As discussed below, the regulation presents both explicit and implicit requirements, and frequently requires that some other regulation or standard be met, which may have both explicit and implicit reqirements of its own. Second, integration must determine what components and subcomponents of a LAM are necessary to assess compliance with these regulations. The integration effort to date indicates that the components of the performance assessment methodology agreed on in the past by the waste management community as a whole are indeed appropriate. These components are scenario development, data evaluation, consequence analysis, probability assignment, and comparison with the standard. Some subcomponents of the existing NRC LAM may be less appropriate. Third, integration will examine current NRC-funded work to see whether all necessary components and subcomponents exist or are under development. An early conclusion of the integration effort has been that there is no comprehensive set of techniques for determining probability of geologic processes and events, although such work has recently been funded. Another apparent lack, not previously identified, is the absence of a formal technique or phase for an assessment of the qualitative suitability of data for use in the performance assessment. Work on these first three goals of integration has begun, although only the examination of regulations and the determination of required components and major subcomponents have progressed very far.

The fourth goal of integration, not yet begun, will be to examine each subcompnent of the LAM to see whether it interfaces correctly with the next subcomponent. Large parts of performance assessment can be viewed as a string of beads: output from the inventory model becomes input for the leaching model; output from the leaching model becomes input for the transport model, and so on. Each interface between codes must be examined by the integration effort to ensure that the beads string together properly. Special attention will be given to the interfaces between codes written by separate contractors.

II. REGULATORY BASIS FOR AN OVERALL LICENSING ASSESSMENT METHODOLOGY

The NRC staff has developed a set of licensing issues that they believe must be addressed by any successful license application.[1] Some of these issues are directly related to specific regulatory requirements; others may not seem at first glance to be related. For example, the licensing issue "When does water contact the waste package?" does not address a regulatory requirement: no part of the regulation places a time limit on resaturation of the rock surrounding the waste package. However, the regulation does address the timing of initial releases from the waste canister to the facility. To model this release, some information must be available on resaturation times; therefore resaturation time is a parameter that must be considered by the LAM. Thus it is not possible to determine what the components of a LAM should be by examining only the regulation. Examining the regulation shows only the minimum set of components that is needed, not the complete set.

A. Explicitly Required Analyses

The performance assessment will be included in the Safety Analysis Report (SAR) to be submitted as a part of the license application. Section 60.21 of the NRC regulations[2] describes the content of the SAR. Among other information, the SAR must include an evaluation of repository performance after permanent closure, assuming both anticipated and unanticipated events. "Anticipated" and "unanticipated" are qualitatively defined to mean "reasonably likely" and "not reasonably likely." The section also requires an analysis of both normal and accident conditions during repository operation and analysis of the extent to which favorable and potentially adverse conditions contribute to or detract from isolation. Satisfaction of these requirements clearly demands scenario development, that is, descriptions of possible sequences of events and processes leading to waste release.

Some consequence analyses are explicitly required. Section 60.111 imposes performance requirements on the repository operations before permanent closure. Section 60.111(a) states that radiation exposures before closure must be within the limits specified in Section 20 and any standards established by the Environmental Protection Agency (EPA). Section 60.111(b) states that the waste must be retrievable for 50 years following waste emplacement. Section 60.113(a.1.ii.A) requires that containment of HLW within the waste package be substantially complete for 300 to 1,000 years. Section 60.113(a.1.ii.B) requires that following this containment period, the release rate from the facility of most radionuclides must not be more than one part in 100,000 annually. Finally, Section 60.113(a.2) requires that ground-water travel time before waste emplacement along the fastest likely path of radionuclide travel be at least 1,000 years from the disturbed zone to the accessible environment. Thus an analysis that develops scenarios and examines operational exposures, retrievability, degradation of the waste package, rates of release from the facility, and pre-emplacement ground-water flow is explicitly required.

B. Implicitly Required Analyses

Other aspects of performance assessment are not explicitly required, but must be carried out in order to comply with some section of the regulation. Section 60.112 is particularly important because it requires a demonstration of compliance with any established EPA standard for both anticipated and unanticipated processes and events. The proposed EPA standard[3] defines "performance assessment" to be "an analysis which identifies those events and processes which might affect the disposal system, examines their effects upon its barriers, and estimates the probabilities and consequences of the events." The standard clearly requires an estimate of the probabilities of events and processes that may affect isolation. Although Section 60.113 refers only to releases that might occur if the system works as designed, assuming anticipated processes and events, Section 60.21 and the EPA standard specifically require examination of releases following unanticipated processes and events. For these reasons, techniques for scenario screening and probability assignment must be part of the LAM.

Although sensitivity and uncertainty analysis are not explicitly required by either the final NRC regulation or the version of the EPA standard formally proposed in 1982, it is generally believed that phrases like "reasonable assurance" and "reasonable expectation" mean that they should be an integral part of the LAM. Draft 4 of the Final 40CFR191[4] is more explicit: Section 191.16(b) refers to "the full range of uncertainties considered in the performance assessment" and how they should be presented.

Section 60.122 sets a number of siting criteria that superficially do not seem to require performance assessment techniques in the demonstration of compliance. Closer examination of the siting criteria, however, reveals that many can only be demonstrated with a performance assessment, because essential site characteristics cannot be directly measured. For example, two favorable conditions, pre-waste emplacement ground-water travel times of substantially more than 1,000 years and mineral assemblages whose capacity to inhibit the transport of radionuclides does not degrade under expected thermal loads, probably cannot be directly measured. Numerical modeling of far-field ground-water travel times, temperature rises away from the canisters, and radionuclide transport would probably be required to demonstrate that these favorable conditions exist. Demonstration that a number of the potentially adverse conditions (Section 60.122(c.1 through 6)) do not exist would also require scenario development and screening, probability estimation, and far-field consequence modeling.

III. COMPONENTS OF AN OVERALL LICENSING ASSESSMENT METHODOLOGY

An overall licensing assessment methodology includes techniques for scenario and probability analysis, analysis of the quantity and quality of data, consequence assessment, and comparison with the applicable rules and standards. Figure 1, a preliminary sketch of the overall postclosure methodology, shows these five components. Preclosure and postclosure methodologies are being developed independently, but the LAM components are undoubtedly the same. Although many of the subcomponents and techniques may be similar, others will differ becuase the preclosure and postclosure environments are so dissimilar. Only the postclosure LAM will be discussed in detail here.

A. Scenario Development

The required functional lifetime of the repository is expected to exceed 10,000 years.[3] The waste package and underground facility will be

COMPONENTS	SUBCOMPONENTS				
SCENARIO DEVELOPMENT	**Waste Package Scenarios:** Base Case Common Cause Failures Design Failures Construction Failures	**Facility Scenarios:** Base Case Long-term Failures Far-field Effects	**Far-Field Scenarios:** Geologic Hydrologic Human Intrusion Repository Induced		
DATA EVALUATION	Judgement of Suitability of Data	Sampling Techniques	Sensitivity Analysis	Uncertainty Analysis	
CONSEQUENCE ANALYSIS	<u>SOURCE TERM</u> Inventory Heat Generation	<u>WATER INFLOW</u> Into the Facility Contact the Waste Package Water contacts the Waste Form	<u>RADIONUCLIDES RELEASED</u> From the Waste Form From the Waste Package From the Underground Facility From the Disturbed Zone From the Far Field to the Accessible Environment		
PROBABILITY ASSIGNMENT	Quality Control Failures	Geologic Events and Processes			
COMPARISON WITH STANDARD	Determine Preemplacement Ground-water Travel Time Must be >1000 years--60.113/a/2	Determine Waste Package Lifetime Must be 300-1000 years--60.113/a/1/ii	Determine Release Rate from Facility Must be $<10^{-5}$ Annually--60.113/a/1/ii	Determine Contribution of Favorable Conditions to and Detraction of Potentially Adverse Conditions from Waste Isolation 60.21/c/1/ii/B	Determine Releases Assuming Anticipated and Unanticipated Processes and Events 60.21/c/1/ii/C and 191

Abbreviation:
60 10CFR60

Figure 1. Major components and selected subcomponents of the preliminary postclosure LAM.

designed and the geologic setting will be chosen to contain and isolate the wastes given anticipated conditions, that is, given the current geologic conditions, proper installation of the facility, and the predicted heat and radiation from the waste. The repository must also be designed to provide adequate isolation in the event of unanticipated conditions. To assist in the design of the repository, selection of the geologic setting, and development of appropriate computer codes, scenarios describing both anticipated and unanticipated conditions must be developed. A comprehensive suite of physically possible scenarios can be used to guide code development and data collection, ensuring that all necessary codes will be available and verified at the time of licensing. Scenarios that could occur at one site might be impossible at a second site; therefore they can be useful in site selection and screening. Waste package and facility design must, by regulation, be site-specific; again, scenarios are necessary to guide the designer. Finally, the NRC regulation requires that the EPA standard be met, and the EPA standard will probably require that a suite of scenarios be developed.[4] Methods for the development of far-field scenarios for the release of radioactive waste have been discussed previously.[5]

2. Probability Assignment

There is consensus in the waste-management community that not all scenarios are equally probable or important. Generally speaking, scenarios that are highly probable, like ground-water flow through the repository, are considered to be most important, and scenarios that are highly improbable, like meteorite impact, least important. Most scenarios are neither highly probable nor highly improbable, and techniques for determining their probabilities closely enough to be useful have not been established. A variety of techniques have been used in the past, but no consensus seems to exist about the best way to determine probabilities of the scenarios of interest. In fact, an early result of the integration task has been to identify the lack of accepted techniques for determining probabilities as a weakness in the current LAM.

Techniques for the determination of probabilities of scenarios and events and processes included in the scenarios are necessary because the EPA standard is probabilistic. It will probably require probabilities to be assigned to all important scenarios so that a complementary cumulative distribution function can be developed and compliance with the standard can be assessed.[4]

C. Data Evaluation

Assuming that a comprehensive suite of scenarios has been developed and their probabilities have been determined, it becomes necessary to estimate the consequences of some of the scenarios. Consequence analysis requires data on site characteristics and on design and degradation characteristics of the waste package and underground facility. Some data may be easy and inexpensive to collect, and presumably data sets will be adequate in those cases. In other cases, however, data will be difficult or expensive to collect, and two questions arise: are a few data enough to show the range of variability in consequences that arise due to this parameter? and how certain is the answer that we get? Three data-evaluation techniques are essential. In the case of voluminous data, some sampling technique that fairly represents the full range of the data must be available, because most codes are only able to deal with point values, not ranges. Sensitivity analysis is especially helpful if the data are few, because it allows the investigator to determine the relative importance of various parameters, so that only important data need be collected. Uncertainty analysis allows the investigator to bound the behavior of the system based on available data.

Sampling techniques that can be used for all types of data of interest to the performance assessment have been discussed in connection with the far-field performance assessment methodology.[6] Latin Hypercube Sampling is a highly efficient sampling technique that allows voluminous data or systems with several parameters to be modeled easily while maintaining an adequate description of all possible outcomes using available data. Sensitivity analysis techniques have been discussed and demonstrated[7,8] in connection with the far-field performance assessment methodology. It seems likely that the same or similar techniques could be used in package- or facility-scale performance assessment. Uncertainty analysis techniques have also been discussed.[9]

Sensitivity and uncertainty analysis and statistical sampling techniques are all quantitative tools for data manipulation. Sensitivity and uncertainty analyses are performed on the results of consequence analyses to determine the impact of the data <u>per se</u> and the impact of uncertainties in the data on consequences. The use of the three techniques implicitly assumes that data have been collected on qualitatively appropriate parameters. This assumption may not be correct. Code development, repository design, and so on, are still in the early stages. Today, it is fairly common practice to use any data that happen to be available and superficially similar to those expected to be gathered during site characterization for model development, code verification, and scoping calculations. Use of these data is entirely acceptable, indeed necessary, for now. It does point out the fact that the data are transparent to the codes, however, and that inappropriate data could inadvertantly be used during performance assessment without giving rise to easily discovered errors. For this reason, the LAM must include at some point a qualitative judgement as to whether the data are indeed appropriate. Appropriateness includes both accuracy or precision of the data and applicability of the collected data to the assumptions in models in which the data will be used.

D. Consequence Analysis

Most consequence analyses use large and sophisticated computer codes. Code development is therefore a major part of the development of an overall LAM. Although DOE is developing and verifying numerous codes for use in consequence assessment, NRC has in some cases supported the independent development of major codes for evaluating the results to be presented by DOE in licensing documents. Code output must be in a form that can be easily compared with criteria and requirements in NRC's 10CFR60 and EPA's 40CFR191.

NRC's far-field performance-assessment methodology is being developed by SNLA Waste Management Systems Division. Far-field flow, transport, and dosimetry codes have been developed and demonstrated as a part of the performance assessment methodology.[10] Previous NRC-funded development of a methodology for performance assessment at the facility scale has been carried out by Golder Associates. This work has depended on existing codes from several sources.[11] NRC's contractor for waste-package performance-assessment methodology is Aerospace Corporation, Eastern Technical Division. Aerospace has found[12] that some existing codes are acceptable for direct use by the NRC in evaluating DOE's waste-package performance assessments, but that for some processes codes are either unavailable or not obviously acceptable.

IV. EXAMINATION OF INTERFACES

The movement of radionuclides from the waste form to the biosphere entails many different physical processes, which are modeled by many different computer codes. Codes have been written or funded by NRC, DOE, EPA, national laboratories, and private industry. It is likely that many of the codes will provide output that is incompatible with the input requirement of the next code. It is essential to identify gaps and weaknesses that might exist in linking the output or response of one model to the next within a given performance assessment methodology. For example, in the calculation of thermomechanical response, it is common to first solve the transient thermal response, which can then be used as input to a mechanical-response code. However, the numerical mesh sizes may differ in the two codes, making it necessary to interpolate or extrapolate the nodal temperatures from the first mesh to the next.

In some cases the output of existing codes cannot be directly compared to the applicable regulations. For example, in evaluating the license application it will be necessary to determine whether the release rate criterion has been met. To the best of our knowledge, no existing codes present the output in the form of a fractional release rate of radionuclides, although one of the performance criteria in the NRC regulation is a fractional release rate of 10^{-5} parts per year. Instead, release is commonly described as a concentration or flux. It is necessary to have a tool that will permit conversion of the output (e.g. flux) to a fractional release rate. In this project, a major effort willl be to ascertain compatibility between consecutive models.

V. SUMMARY

The regulations and standards against which DOE's performance assessments will be judged are being examined to see what results are explicitly and implicitly required, and hence what the components of performance assessments and the LAM should be. A performance assessment that meets the requirements of the NRC regulation must include scenario analysis, probability assignment, data evaluation, consequence assessment, and comparison with the standard. The LAM must include techniques for assessing the results generated by these components. Probability assignment has been identified as a component that is currently missing from the LAM. Qualitative judgement of data is a missing subcomponent. Much work remains on the LAM. Subcomponents of each of the five components discussed here must be identified. Codes and other tools to implement each subcomponent must be identified and evaluated. The interfaces between codes must be carefully examined. NRC can use the results of this task to prioritize its allocation of funds and to guide DOE in its collection of data and design of engineered barriers.

V. REFERENCES

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A-1165

TOTAL FOR 1183.010, 1183.020, 1183.030, and 1183.040

March 1985

THIS IS AN ESTIMATE ONLY AND MAY NOT MATCH THE INVOICES SENT TO NRC BY SANDIA'S ACCOUNTING DEPARTMENT.

	Current Month	Year-to-Date
I. Direct Manpower (man-months of charged effort)	1.4	9.9
II. Direct Loaded Labor Costs	16.0	106.0
Materials and Services	0.0	0.0
ADP Support (computer)	0.0	0.0
Subcontracts	1.0	11.0
Travel	1.0	5.0
Other	1.0	-1.0
TOTAL COSTS	19.0	121.0

Other = rounding approximation by computer

III. Funding Status

Prior FY Carryover	FY85 Projected Funding Level	FY85 Funds Received to Date	FY85 Funding Balance Needed
88K	488K	400K	None

A-1165, Task IV
1183.040
March 1985

THIS IS AN ESTIMATE ONLY AND MAY NOT MATCH THE INVOICES SENT TO NRC BY SANDIA'S ACCOUNTING DEPARTMENT.

		Current Month	Year-to-Date
I.	Direct Manpower (man-months of charged effort)	0.0	0.1
II.	Direct Loaded Labor Costs	0.0	1.0
	Materials and Services	0.0	0.0
	ADP Support (computer)	0.0	0.0
	Subcontracts	0.0	-1.0
	Travel	0.0	0.0
	Other	0.0	-1.0
	TOTAL COSTS	0.0	-1.0

Other = rounding approximation by computer

III. Funding Status

Prior FY Carryover	FY85 Projected Funding Level	FY85 Funds Received to Date	FY85 Funding Balance Needed
None	50K	50K	None

A-1165, Task III
1183.030
March 1985

THIS IS AN ESTIMATE ONLY AND MAY NOT MATCH THE INVOICES SENT TO NRC BY SANDIA'S ACCOUNTING DEPARTMENT.

		Current Month	Year-to-Date
I.	Direct Manpower (man-months of charged effort)	0.5	1.6
II.	Direct Loaded Labor Costs	6.0	18.0
	Materials and Services	0.0	0.0
	ADP Support (computer)	0.0	0.0
	Subcontracts	0.0	0.0
	Travel	0.0	0.0
	Other	0.0	1.0
	TOTAL COSTS	6.0	19.0

Other = rounding approximation by computer

III. Funding Status

Prior FY Carryover	FY85 Projected Funding Level	FY85 Funds Received to Date	FY85 Funding Balance Needed
52K	202K	150K	None

A-1165, Task II
1183.020
March 1985

THIS IS AN ESTIMATE ONLY AND MAY NOT MATCH THE INVOICES SENT TO NRC BY SANDIA'S ACCOUNTING DEPARTMENT.

		Current Month	Year-to-Date
I.	Direct Manpower (man-months of charged effort)	0.2	4.3
II.	Direct Loaded Labor Costs	2.0	47.0
	Materials and Services	0.0	0.0
	ADP Support (computer)	0.0	0.0
	Subcontracts	1.0	8.0
	Travel	1.0	5.0
	Other	1.0	-1.0
	TOTAL COSTS	5.0	59.0

Other = rounding approximation by computer

III. Funding Status

Prior FY Carryover	FY85 Projected Funding Level	FY85 Funds Received to Date	FY85 Funding Balance Needed
36K	86K	50K	None

A-1165, Task I
1183.010
March 1985

THIS IS AN ESTIMATE ONLY AND MAY NOT MATCH THE INVOICES SENT TO NRC BY SANDIA'S ACCOUNTING DEPARTMENT.

	Current Month	Year-to-Date
I. Direct Manpower (man-months of charged effort)	0.7	3.9
II. Direct Loaded Labor Costs	8.0	40.0
Materials and Services	0.0	0.0
ADP Support (computer)	0.0	0.0
Subcontracts	0.0	4.0
Travel	0.0	0.0
Other	0.0	0.0
TOTAL COSTS	8.0	44.0

Other = rounding approximation by computer

III. Funding Status

Prior FY Carryover	FY85 Projected Funding Level	FY85 Funds Received to Date	FY85 Funding Balance Needed
None	150K	150K	None