UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DEC 14 1984

MEMORANDUM FOR: Robert E. Browning, Director
Division of Waste Management

FROM: Tilak Verma, Senior On-Site
Licensing Representative
Salt Repository Project (SRP)

SUBJECT: SRP SITE REPORT FOR THE WEEK OF
DECEMBER 3, AND DECEMBER 10, 1984

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WM Project 16
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1. Reviewed the information provided by the WMRP for the QA Review of DOE-SRPO on December 18 and 19, 1984. DOE-SRPO QA Manual was also reviewed in preparing for the Review Meeting.

2. DOE-SRPO QA Program is being audited (December 11, 12 and 13, 1984) by the DOE-Chicago Office. It is considered as an internal QA audit. I wanted to attend this audit as an NRC observer. I was told by Neff that NRC presence would inhibit openness in his staff and therefore, he did not think that it was appropriate for me to attend this QA audit. I discussed this issue with Mike Bell and conveyed to him that if I am denied access to these technical meetings, then this would affect my effectiveness.

3. Received and reviewed DOE-SRPO's comments on "Draft Generic Technical Position on Licensing Assessment Methodology for HLW Geologic Repositories, July 1984" and "Issue-Oriented Site Technical Positions (ISTP)". DOE-SRPO staff is quite critical of these technical positions. I would be interested in working with the Waste Management Division staff in responding to some of these comments.

4. I have received a set of seven draft EAs for the salt sites. The sets do not include Chapters 1 and 7.

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Senior On-Site Licensing Representative
Salt Repository Project

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December 12, 1984

Ralph Stein, Director, Engineering and Licensing Division, DOE-HQ

SUBJECT: DRAFT GENERIC (NRC) TECHNICAL POSITION ON LICENSING ASSESSMENT METHODOLOGY FOR HLW GEOLOGIC REPOSITORIES, JULY, 1984

This memo provides comments on the subject document as requested in your October 18, 1984 memo to me and the other CRWM project managers. The NRC's generic technical position document represents a significant first step in the NRC's program of defining licensing procedures. It provides a basis for the development of detailed procedures for the demonstration of compliance by performance assessment methodology during the licensing process. However, this is a draft document which we expect to be modified based upon comments and face-to-face discussions.

Our review did not reveal unexpected technical positions or attitudes. The document is focused on the uses of performance assessment and how licensing assessments may be carried out during the site characterization process. Consequently the draft position emphasizes the application of these assessments to the Site Characterization Plan. This point was recognized by several commenters who felt that the NRC has failed to realize or remember that the SCP will be continously updated and expanded. The impression given in this document's text is that the assessments are expected to be finalized in the initial submission of the SCP. We however believe that the assessments will be growing and expanding during both the site characterization and in situ testing programs. It is not unlikely that even during the performance confirmation studies, which will continue during emplacement operations, additional development and expansion of the licensing assessments will occur.

In finalizing 10 CFR Part 60 the Commission was very careful to articulate its position concerning compliance with the EPA standard, treatment of uncertainties, and the use of both quantitative and qualitative analyses in arriving at its findings of reasonable assurance of no unreasonable risk to the public health and safety. The NRC staff may have placed greater emphasis in the technical position on the importance of the quantitative assessments than is warranted on the basis of the Commission's position; and likewise, may have underemphasized the importance of the qualitative assessments, particularly as they relate to the reasonable assurance findings.

It is also believed that the draft position goes too far in interpreting what the EPA standard will require. Laying aside the fact that the EPA standard is not yet finalized, the Commission has been very cautious about incorporating

bottom-line probablistic risk assessments into the licensing process. As one intent of the EPA rulemaking is to require just that, there is an as yet unresolved question about how the Commission will choose to exercise its decision-making authority and whether the Commission will accept EPA's direction on how to implement the EPA standard. By committing to the EPA view at this time, NRC staff has made not only a technical decision about how the EPA standard should be met, but also a policy judgment which the Commission itself should probably review. This decision has implications with respect to licensability of a site. The discussion of performance assessment in the draft position has been very much affected by what NRC staff expects the EPA standard to require and by assumptions underlying the Standard about such things as the existence of adequate models, the ability to make bounding assumptions, the ability to quantify uncertainties, and the prominence which is appropriate for quantitative models in licensing decision. These requirements and assumptions have ramifications with respect to licensability of a repository which NRC staff should be asked to consider further in revising the draft position.

In addition to noting that there are some typographical errors and the need for editing portions of the text, which are not detailed in this letter, there are additional points that deserve comment.

1. It is believed that the overall position is consistent with SRP intentions. Clarification however is needed on just what NRC expects to see in the SCP and how it should be presented, if it has a preference. Clarification is needed also on the approach to be taken for evaluating compliance with the EPA criteria for releases--either subsystem numerical performance allocation, overall system performance or some combination.

2. We are concerned about the extensive use of the word "probability" throughout the document. We recognize the EPA standard requires probability data. However, they provided "probability" estimates for many events as part of the analyses used to establish the standard. In cases where it is not possible for the project to develop better estimates, the EPA estimates may be used. In such cases DOE would not have to justify the probabilities used in the analyses, contrary to NRC's guidance on page 7, but would have to rely on the EPA's estimates.

3. The summary of Part 60 technical requirements is not complete. Due to the bifurcated nature of the Part 60 rulemakings, technical and information requirements are scattered throughout the regulation and many are implied. That is, technical requirements imply as yet unstated information requirements and vice versa. Only a careful content analysis will draw them out. A limited listing such as is in the draft position identifies only the obvious ones; and there is a danger that others, many of which are important to confidence in repository performance, will be overlooked. To the extent this does occur, the basis for making the reasonable assurance determination will be flawed. It is recommended that NRC identify explicitly and comprehensively all of the information requirements that must be

addressed by DOE so that the licensing assessment methodology NRC is seeking from DOE at the SCP stage can be sufficiently comprehensive.

4. We are concerned about the frequent use of the term "reliability." This word needs to be defined if it is to be applied to a static system with only a few components or that is dependent on a single physical property. It has a definite meaning when talking about electronic or mechanical systems with thousands of interacting components where reliability is lost when even one component fails, but when the component (that is, barriers) relies on a limited set of physical properties the concept of reliability is altered.

5. Reliance on "natural analogs" (page 16), while a desirable goal, may not be possible. The statement "must be justified by using the results of site-specific experiments and by comparing with appropriate natural analogs" is too strong. We may have to rely on only site-specific experiments.

6. NRC provides guidance for meeting regulations dealing with operational safety in Section 3.3.1. It should be pointed out to NRC that the projects are planning to address such issues in companion plans to the SCP.

7. Section 2.0, Technical Position in Licensing Assessment Methodology, is troublesome. Earlier, it appeared DOE was to develop a "licensing assessment methodology," which was understood to be a decision strategy laid out in the SCP that would guide DOE's assessment as to whether its license application would provide NRC with a sound basis for arriving at the reasonable assurance findings. As the information for preparing the application would be completed as a result of the site characterization, the licensing assessment methodology would guide the preparation of the SCP. The present discussion confounds in several ways: first, it appears to be prescribing the licensing assessment methodology itself; second, it appears to require as part of the methodology what would/is supposed to be produced in site characterization; third, it does not provide a perspective on the quantitative/qualitative mix that is consistent with the Commission's articulated position. NRC should be asked to clarify this section.

8. The NRC always assumes that a waste package is surrounded by backfill at the time of emplacement. For the salt project, backfill, even crushed salt, may not be justified. It would be useful to understand NRC's position on the extent of the engineered barrier system in such a system.

9. There is concern about use of the words "all", "should include", and "complete" in the guidance. Projects should consider all physical or chemical properties important to isolation. The phrase "important to isolation" should be included since it bounds the task. NRC should not tell DOE what must be included in its models (page 24). It is appropriate for NRC to tell DOE what processes they should consider

when developing models. The word "comprehensive" is preferrable to "complete" when discussing issues (page 25).

10. Referring to Section 3.1.1, Approach to Performance Assessment in the Content of Licensing Assessment, the characterization of how the semiquantitative and qualitative assessments are to be used seems unduly narrow. It is believed that the Commission will place greater reliance on them than the NRC staff seems to suggest. The staff discussion should be consistent with and elaborate upon the Commission's position.

    Second, NRC staff has implied its licensing review plan in this discussion as it tells what elements DOE should address in the licensing assessment methodology. The review plan then implies approaches NRC expects DOE to take in siting, designing, testing, modeling, etc. In other words, NRC is using an articulated model of how DOE is going to do its job. It would be most helpful if NRC staff would make these assumptions explicit, and how the assumptions will contribute to being able to make the reasonable assurance findings.

In summary, while we found the draft position to be of real assistance, it raised additional questions. A recent paper presented at GAIN '84 (attached) by Bob Wright of the NRC clarified certain points. We would expect that a future revision of the draft position will further reduce the questions left unanswered. We request that we have an opportunity to comment on the position again before the position is finalized and we are available to discuss our comments further with you or the NRC staff if this would facilitate NRC in finalizing their position.

J. O. Neff

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Enclosure:
October 15, 1984, Licensing Information Needs for a High-level Waste Repository, by R. Wright, J. Greeves, M. Logsdon (GAIN '84 Symposium)

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GAIN 84 SYMPOSIUM

October 15, 1984

LICENSING INFORMATION NEEDS FOR A HIGH-LEVEL WASTE REPOSITORY

by
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U. S. Nuclear Regulatory Commission

INTRODUCTION

This paper has been prepared to present the views of the Nuclear Regulatory Commission (NRC) staff on the information needs for licensing findings during the several phases of development of a repository for high-level waste (HLW). In particular, attention is given to the information and analyses that will be needed to demonstrate, for construction authorization purposes: repository constructibility, waste retrievability, waste containment, and waste isolation.

We hope that the paper provides background for the discussions during the next several days and will make a contribution to the success of this important symposium.

OVERVIEW OF THE LICENSING PROCESS

Licensing information needs are controlled, of course, by the steps in the licensing process described in NRC's regulation on an HLW repository--10 CFR 60 (Ref. 1). As stated in Reference 2 (p. 28195):

> The licensing process will begin with the submission of a license application with respect to a site that has been characterized. Following a hearing, DOE [U.S. Department of Energy] may be issued a construction authorization. Prior to emplacement of HLW, DOE would be required to obtain a license from NRC; an opportunity for hearing is provided prior to issuance of such a license. Permanent closure of the geologic repository and termination of the license would also require licensing action for which there would be opportunity for hearing.

Figure 1 shows the licensing steps plotted on a horizontal time line, taken from DOE's draft "Mission Plan for the Civilian Radioactive Waste Management Program" (Ref. 3). Five kinds of repository activities are listed below the time line.

It is expected that geotechnical assessment and testing will continue, without interruption, from the beginning of site characterization up to permanent closure. The nature of the activities will change, with time, for two reasons.

1) Different issues are under consideration in the sequential licensing steps; hence, licensing information needs are different.

2) More importantly, the opportunities for testing expand as repository development progresses.

When a candidate site is first selected, geotechnical investigations are limited to the surface and boreholes. With the establishment of an exploratory shaft (or shafts) and an underground test facility, site characterization can proceed with direct access to the repository host rock. Subsequently, construction permits greater access to the host rock over larger areas. Finally, the emplacement of waste permits first-hand observation of the effects of heat and radiation on the host rock.

The continuum of effort provides an expanding body of knowledge on which licensing findings can be based with increasing levels of confidence. This paper focuses on the first key event in licensing--construction authorization.

What, then, is the basis for granting the construction authorization?

BASIS FOR GRANTING THE CONSTRUCTION AUTHORIZATION

After DOE submits a license application for a site that has been characterized, the Commission may authorize construction. The decision by the Commission requires a finding that the radioactive material described in the application can be received, possessed and disposed of without unreasonable risk to the health and safety of the public (10 CFR 60.101(b)).

Further, the performance objectives and the qualitative criteria of Subpart E of 10 CFR 60 must be satisfied to support such a finding of no unreasonable risk. Because of the importance of the performance objectives, they are described in summary fashion below. The qualitative criteria are also important; however, they are more numerous and more specific than the performance objectives. Thus, a discussion of the criteria would extend beyond the bounds of this overview paper.

The Commission requires a DOE proposal to be based on a multiple barrier approach. An engineered barrier system is required to compensate for uncertainties in predicting the performance of the geologic setting. Similarly, because the performance of the engineered barrier system is also

subject to considerable uncertainty, the geologic setting must be able to contribute significantly to isolation. Separate performance objectives apply to the two types of barriers.

Figure 2 presents, in summary form, the performance objectives. For the overall repository, the requirement is satisfaction of the U.S. Environmental Protection Agency (EPA) standard for high-level waste. Although not in final form, the drafts of the EPA standard set a limit for radiation exposure to members of the public during repository operations; and, after repository closure, limit the cumulative release to the accessible environment for selected radionuclides, over a period of 10,000 years following closure of the repository.

For the engineered barrier system, there are two sets of performance objectives. One set is applied to the operational period during which waste is emplaced; the other is applied to the period after permanent closure, which represents the end of human activities at the site. During the operational period, protection must be provided against radiation exposure to the workers and to the public and against release of radioactive material. The standards for workers are those set by the NRC in 10 CFR 20 for licensed nuclear facilities of all types, together with the portion of the EPA standard applicable during repository operation. In addition, the Commission requires that the engineered barrier system be designed and constructed so the waste can be retrieved for a period of 50 years after initial emplacement. After permanent closure, the waste package is required to effectively contain the waste for a period between 300 and 1000 years. In addition, the engineered barrier system is required to limit annual releases to 1×10^{-5} of the radionuclide inventory present at 1000 years.

For the geologic setting, pre-emplacement groundwater travel time must be more than 1000 years, as measured from the edge of the zone that would be disturbed by repository construction and waste emplacement, to the accessible environment.

Reasonable Assurance

One purpose in outlining the performance objectives of 10 CFR 60 is to introduce a significant point: The licensing findings must be made in the face of substantial uncertainties about the performance of a repository system over very long periods of time. There will, of necessity, be extensive reliance on quantitative models to calculate expected repository performance and to estimate the uncertainties. However, not all of the uncertainties will be quantifiable. Therefore, quantitative models alone will not provide a

sufficient basis for making the required licensing findings. The Commission will have to place strong reliance on qualitative understanding, descriptive models, and expert judgment (10 CFR 60.101(a)(2)):

> A reasonable assurance, on the basis of the record before the Commission, that the objectives and criteria will be met is the general standard that is required. For §60.112, and other portions of this subpart that impose objectives and criteria for repository performance over long times into the future, there will inevitably be greater uncertainties. Proof of the future performance of engineered barrier systems and the geologic setting over time periods of many hundreds or many thousands of years is not to be had in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with those objectives and criteria.

The term "reasonable assurance" has attracted attention from individuals interested in 10 CFR 60 and its application. Some commentors have suggested that a statistical definition of acceptability should be used (Ref. 4) or that "complete assurance", being more conservative, is needed.

The Commission has addressed these views in Reference 2 (p. 28204):

> In the Commission's view, the "reasonable assurance" standard neither implies a lack of conservatism nor creates a standard which is impossible to meet. On the contrary, it parallels language which the Commission has applied in other contexts, such as the licensing of nuclear reactors, for many years. See 10 CFR 50.35(a) and 50.40(a). The reasonable assurance standard is derived from the finding the Commission is required to make under the Atomic Energy Act that the licensed activity provide "adequate protection" to the health and safety of the public; the standard has been approved by the Supreme Court. <u>Power Reactor Development Co. v. Electrical Union, 367 U.S. 396, 407 (1961)</u>. This standard, in addition to being commonly used and accepted in the Commission's licensing activities, allows the flexibility necessary for the Commission to make judgmental distinctions with respect to quantitative data which may have large uncertainties (in the mathematical sense) associated with it.

Three final comments can be made. First, it is perhaps worth observing that the use of qualitative judgment does not necessarily work to loosen the standard; in a sense, it tightens the standard. This is because the licensing board will need to consider not only the calculations on repository performance but also the qualitative conceptual models and the uncertainties therein.

Second, the reasonable assurance standard is not unique to the NRC. A cursory check of the United States Code reveals scores of provisions for federal agencies to make determinations with reasonable assurance. The activities covered in this way are highly diverse: for example, agriculture, banking, commerce, conservation and customs--to name a few. In such areas, reasonable assurance is a workable standard for decision making in the face of uncertainty.

Third, an important element in the Commission's ability to authorize construction will be the analysis of uncertainties provided in the license application. It is expected that DOE will rigorously identify and analyze the uncertainties in repository performance and analyze these with respect to the performance objectives.

Figure 3 is an attempt to illustrate conceptually the reduction of uncertainty during site investigation. Intensive investigation takes place during site characterization, and progress is made in reducing uncertainties. Progress is especially vigorous once underground testing is under way. After a time, a point is reached when additional investigation provides marginal returns in the reduction of uncertainties. This point is beyond the steep portion of the curve, when we could expect the license application to be submitted. Subsequent findings (i.e., license to receive waste; license amendments for permanent closure and license termination) will be based on additional information obtained during the performance confirmation program (10 CFR 60.140). Thus, the confidence level will be highest when the irrevocable decision on permanent closure is faced. The reasonable assurance standard will be applied to each NRC licensing decision.

REVIEW OF THE LICENSE APPLICATION

In processing a DOE license application, the NRC staff will review DOE's description of the repository and DOE's assessment of the performance of the site and design with respect to the performance objectives and criteria in Subpart E of 10 CFR 60. The general process for NRC licensing assessments is illustrated in Figure 4.

With respect to each required licensing finding, the staff will evaluate the data and analyses presented in the Safety Analysis Report and its referenced

documents. In some critical areas, such as experimental determination of radionuclide solubility or the analysis of pump tests, the staff may perform confirmatory tests or reanalyze primary data.

Following the review of DOE's data, the staff will evaluate and comment on DOE's assessments of compliance with the performance objectives. The evaluation will emphasize the completeness and adequacy of (1) models and model inputs, (2) uncertainty analyses, and (3) consideration of alternative interpretations. Assessments will be made of DOE's treatment of uncertainties in

(1) the basic physical and chemical phenomena and processes;

(2) constitutive relationships and conceptual models that are used to approximate the physics and chemistry of the system;

(3) mathematical models and calculations that are used to describe constitutive relationships and conceptual models and to reduce primary data; and

(4) primary data, including uncertainties in the methods and procedures used to collect the primary data.

In parallel with the evaluation of the DOE performance assessments, the staff will formulate its own conceptual models of the repository and its engineered and natural systems. Scenario analyses will be developed for the sequences of processes or events that would affect performance. Mathematical models will then be used to assess compliance with the performance objectives of Subpart E in selected areas.

INFORMATION NEEDS FOR THE LICENSE APPLICATION

As illustrated by Figure 1, and as discussed above, it is likely that geotechnical testing at a repository site will continue over many years: through site characterization, construction, and operation up to the point of permanent closure. Site characterization information provides the principal support for the license application. Performance confirmation information provides additional support for all licensing decisions, especially issuance of a license to receive waste and amendments for permanent closure and termination of the license.

This concept of the continuum of testing may provoke questions about the content of the license application: How does the application accommodate long-term, ongoing tests that start during site charaterization and continue

through submittal of the license application? What is enough in situ testing during site characterization? What testing is needed to satisfy the constructibility and retrievability requirements?

Ongoing Tests

It is expected that the license application submitted by DOE will be complete and will stand on its own in addressing the requirements of 10 CFR 60. Experience in licensing reactors has demonstrated that the introduction of new test data during consideration of a license application has an inevitable consequence: delay. Efficiency in considering DOE's license application will be improved if the licensing hearing can focus on data in the application without consideration of later test results.

What, then, is to be done about tests that are unfinished at the time the license application is submitted? Under what conditions can these results from unfinished tests be used? The answer to both questions is embodied in a simple phrase--predictability of the results. Consider two illustrative examples, in which results are available from the first year of:

(1) a three-year underground test of creep in salt and
(2) a three-year underground thermal test in a crystalline rock.

In example (1), the objective is to determine the rate of creep at a site chosen by DOE. Numerical models of salt creep are available from earlier work by the DOE in Louisiana, work by German investigations at Asse, and published works by companies that mine salt at various depths below surface. However, some parameters affecting creep (such as impurities or inclusions in the test samples have not been well defined nor represented in the predictive models. Early results from the test in example (1) show that the measured creep is not close to that predicted, for undetermined reasons. These early results would not be suitable for a license application. More conclusive test results would be required. In example (2) the objective is to test the thermal response of a crystalline rock at repository depth. For the purpose of this illustration, it is assumed that some tests had been previously done by DOE in a similar type of rock with similar geologic and geomechanical characteristics. Testing data of a generic nature on crystalline rock are also available. Early results of this test indicate that the thermal characteristics are reasonably approximated by the predictive model previously developed. The early results from the first year of testing may be suitable for a licensing application.

In summary, early results from an ongoing, but incomplete, test can be used in the license application, provided it can be demonstrated that the outcome of the test is predictable from the early results. The rationale can take various

forms. For example, it may be based on the conformance of the test results to a predictive numerical model for the test, or it may be based on the similarity of the test results to previous tests done under similar conditions elsewhere.

What Is Enough Testing?

How is DOE to determine what is enough testing and investigation to support a license application?

In a series of interrelated actions, the NRC staff has expressed its views on several aspects of this question. Some of these views relate to the Basalt Waste Isolation Project at Hanford, Washington, but they are believed to be applicable to other locations.

In the "Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project" (Ref. 5), the staff noted that a key step in determining testing needs is early identification of performance requirements for various system components. This recommendation was also provided to DOE in NRC's comments on the draft of the DOE Mission Plan (Ref. 6). 10 CFR 60.113(b) gives DOE flexibility, on a case-by-case basis, to propose tradeoffs among system components, both natural and engineered. Tentative identification of component performance goals is an essential prerequisite to establishing what is a necessary and sufficient level of testing. During site characterization, therefore, this matter can have major impact on the schedule: for example, whether site characterization can be completed within the 49 months assumed in the current DOE reference schedule or in the 133 months described in alternate plans (Ref. 3). Until DOE determines the importance of the overall performance of the rock close to the underground facility, it will not be clear how much information concerning the thermal effects of waste emplacement on the host rock and groundwater will be required.

We believe it would be prudent for DOE to make an early decision, guided by the performance objectives of 10 CFR 60.111, as to what the performance should be for the individual components. This decision should take into account the Commission's expectations that, where practical to do so, the performance of the waste barriers is to be enhanced so as to provide greater confidence in licensing judgments. The performance goals should be set early in the program because of the long lead times needed for some tests. Failure to do so could preclude the collection of necessary information in time for licensing, as shown in the schedule of Figure 1.

Another action by NRC is to review drafts of DOE test plans. For example, DOE released the Draft Exploratory Shaft Test Plan for the Basalt Waste Isolation Project (Ref. 7) and met with NRC staff and other interested parties to discuss

this plan. Although the NRC staff (Ref. 8) agreed that the proposed test plan includes the kinds of tests that are appropriate for license application findings, it expressed a concern that the plan does not address the issue of coupled thermomechanical and hydrologic conditions associated with waste emplacement. Neither direct testing of coupled behavior, nor demonstration that coupled behavior is unimportant to performance, is presented in the test plan. Further, without early identification of performance goals for subsystem components to help address the question of "what is enough?", the staff was not convinced that the amount of testing proposed will be necessary and sufficient. The need for additional testing cannot be evaluated until DOE establishes (1) how much performance will be expected from the various engineered and natural system components and (2) the degree of conservatism built into performance analysis.

Constructibility and Retrievability

Another difficult question is: "What is necessary and sufficient in terms of information needs to demonstrate constructibility and satisfaction of the retrieval requirement?"

Such demonstration, by DOE, is expected to be based on testing and proven experience with analogous activities. Some analyses that involve mathematical models will be needed. For example, it is expected (Ref. 5) that such analyses will be performed to show the impact of construction and waste emplacement on the stability of underground openings.

Constructibility and retrieval considerations will have a significant impact on the design of a geologic repository. DOE can consider a wide range of alternative approaches which can vary from simple to complex--even unconventional. DOE's choice will, no doubt, take into consideration cost, schedule, and feasibility as well as licensing issues.

How much information is needed for construction authorization will be specific to both the site and the design. This point can best be illustrated by giving a few examples. First, one may want to consider whether there is any concern with constructibility in a tuff formation at the Nevada Test Site (NTS). A large amount of experience with construction and excavation in nonwelded tuff has been developed at the NTS. Conversely, there is little experience with welded tuff, and broken core recovered from boreholes in welded tuff raises a question about constructibility in this rock. Therefore, it is expected that more information in terms of demonstration would be needed for a repository located in welded tuff compared with one located in nonwelded tuff for which a large amount of prior experience has been gained.

Concepts for waste retrieval provide another example. DOE and NRC have looked at a wide variety of such concepts (Ref. 9). These have included consideration of floor, rib, and room emplacement of the waste. Some concepts call for early backfill; others provide for backfill just before closure. As with constructibility, the extent of demonstration needed will depend on the novelty of, experience with, and complexity of a particular design.

For a third example, consider a hard rock site with the waste placed in short, vertical holes in the floor without backfill. Here, DOE can apply the experimental results from the CLIMAX test facility, Nevada Test Site, where conditions are similar. However, if waste emplacement is proposed in long, horizontal holes, a novel approach suggested in some concepts (Ref. 9), the staff would expect appropriate demonstrations to be included in the site characterization program (Ref. 5).

In summary, the extent of information needed for any particular site and design will have to be based for the most part on engineering judgment backed up by analyses. As part of the ongoing NRC/DOE interaction, discussed below, the NRC staff expects to review DOE test plans dealing with constructibility and retrievability and evaluate them for sufficiency.

ANALYSIS OF WASTE ISOLATION IN THE LICENSE APPLICATION

In the license application, DOE has the responsibility to establish that the evaluations of component, subsystem and system behavior demonstrate compliance with the criteria of 10 CFR 60. To this end, the performance assessment methods should logically and fully cover all significant performance-related questions.

The following questions must be addressed for the overall system and for each appropriate subsystem and component:

(1) What are the spatial and temporal scales that are important to the performance of the system or component?

(2) What are the pre-waste physical and chemical properties of the engineered materials and of the environment that are important to the performance of the system or component?

(3) What are the types, probabilities and natures of natural, human-induced, and repository-induced changes, including both anticipated and unanticipated events and processes, that would affect repository performance?

(4) What are the effects over time on repository performance of natural, human-induced, and repository-induced changes, including both anticipated and unanticipated events and processes?

For each of these questions, DOE should provide a technical rationale that addresses the following considerations (Reference 10):

What is the technical approach that is used to make predictions or to bound the range of repository performance as it applies to the question?

How have scenarios that describe anticipated and, as appropriate, unanticipated events and processes been identified, screened and quantified? How have non-independent effects between events and processes been addressed in the analyses?

What are the alternative conceptual models that are used to describe the system, subsystem or component, and how well do site-specific or design-specific data and observations support these conceptual models?

What are the mathematical models that are used to predict environments or to describe the consequences of scenarios, and do these mathematical models adequately represent the conceptual models? Do the analytical and/or numerical models that are actually applied adequately represent the mathematical models?

How have the analytical and numerical models been documented, verified, benchmarked, and validated to the extent practicable?

What are the uncertainties in the assessment, and how have these uncertainties been addressed?

The following comments, taken in part from Reference 10, address particular points requiring some elaboration for each of the four performance objectives.

Containment

The DOE programs to address the performance objective for containment will likely be based on both a materials-engineering analysis and an assessment of the anticipated physical and chemical properties of the waste package environment through the period of containment. The Safety Analysis Report, in

the license application, should identify failure modes and the consequences of failures both for the performance of the waste package and for the performance of the overall repository system. The assessment of the waste package performance is expected to address the potential impacts of coupled processes (i.e., thermal-mechanical-hydrological-chemical-radiologic interactions) on the waste package environment. Additionally, the Safety Analysis Report should explain the approach DOE used to extrapolate empirical models of waste package environment and waste package performance for the full duration of the containment period.

DOE should describe and evaluate the conceptual and mathematical models that are used to address the performance of the waste package. The evaluation of the models should consider

(1) the data needs and status of data availability;

(2) the degree to which the available data support alternative conceptual models;

(3) the degree to which mathematical models represent the conceptual models;

(4) the documentation, verification, benchmarking, and validation of mathematical models and codes; and

(5) the impacts of all sources of uncertainty on the estimate of the performance of the waste package.

<u>Release Rate</u>

Radionuclide decay and the production of daughter radionuclides must be accounted for in the calculation of the radionuclide inventory present 1000 years after permanent closure. Any radionuclides that are leached from the engineered barrier system before 1000 years following permanent closure should be included in the calculated total inventory at 1000 years to ensure that all calculations of source term reflect the appropriate concentrations of all radionuclides that must be considered. The methodology for performing quantitative assessments of the release rate should address the determination of the time-dependent radionuclide source term and the approach to determining radionuclide transport from the waste package, through the engineered barriers, to the boundary of the engineered barrier system. The Safety Analysis Report must address the potential coupling of physical and chemical processes in and adjacent to the engineered barrier system. Evaluation of the models used is expected to consider the five elements described above under "Containment".

Pre-Emplacement Groundwater Travel Time

As stated in 10 CFR 60.113(2), the pre-emplacement groundwater travel time is calculated along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment. This requires calculations of the travel time along the locus of potential flow paths from the disturbed zone boundary to the accessible environment boundary. The disturbed zone, as defined in 10 CFR 60.2, is that portion of the controlled area where physical or chemical properties have changed as a result of underground facility construction or as a result of the heat generated by the emplaced waste so that the resultant change in properties may have a significant effect on repository performance.

For the purpose of assessing this performance objective, the following are required:

(1) the full range of supportable, alternative mathematical models (e.g., porous-flow-equivalent and dual-porosity flow models); that is, models that are

(a) consistent with the conceptual models of the groundwater flow system;
(b) verified, benchmarked, and validated to the extent practicable; and
(c) calibrated with site-specific data;

(2) defensible boundary conditions;

(3) a spatial distribution of hydraulic parameters (horizontal and vertical hydraulic conductivity and effective porosity) that is based on field measurements and a defensible method of interpolation; and

(4) a discussion of uncertainties in models, data, and computations sufficient to demonstrate that the full range of feasible performance has been considered.

EPA Standard

The proposed EPA standard (40 CFR 191 (Ref. 1)) addresses releases of radionuclides to the accessible environment on a probabilistic basis. To address releases of radionuclides on a probabilistic basis, it is necessary to evaluate events, processes, and conditions that may affect repository performance. The evaluation includes

(1) the identification of an appropriate set of release scenarios,

(2) the determination of the consequences of release scenarios,

(3) the determination of the probability of occurrence of each release scenario, and

(4) the combination of the risks of releases into a cumulative complementary distribution function that assesses the probability that the EPA standard will be exceeded.

We recognize that the identification of scenarios is likely to require the use of subjective judgment. However, any method used to identify scenarios should

(1) be done in a systematic, unbiased manner to mitigate the subjectivity to the fullest extent possible;

(2) be throughly documented to enable review by affected Indian tribes, State and Federal Governments, the technical community, and other interested parties; and

(3) encourage strong involvement of all these interested parties in order that they may be satisfied that their concerns have been addressed fairly.

The assessment of the consequences of the release scenarios should consider (1) the source term, that is, time-dependent radionuclide releases from the engineered system, and (2) radionuclide flow and transport from the engineered system, through the natural system, to the accessible environment. The approach to radionuclide transport should consider alternative conceptual models of transport phenomena that include (1) advection, (2) dispersion, (3) geochemical retardation (e.g., sorption, solubility control, diffusion); and (4) branching decay. DOE should evaluate all mathematical models that are used to assess the consequences of the release scenarios, taking in to consideration the five elements described under "Containment".

To comply with the NRC and EPA regulatory criteria, two distinct evaluations of scenario probabilities are required. The NRC requires a qualitative classification of events and processes as being either anticipated or unanticipated based, in part, on the geological record during the Quaternary Period (see definition of anticipated and unanticipated processes and events in 10 CFR 60.2). The performance objectives for the engineered waste-isolation subsystems must be achieved only for anticipated events and processes, but compliance with the EPA standard must be achieved for both anticipated and unanticipated events and processes. Additionally, the proposed EPA standard requires a quantitative probability (or frequency) estimate of releases to the accessible environment from all significant processes and events that may

affect the disposal system. Releases, taking into account all such processes and events, must not exceed the limits of the standard.

The assignment of numerical probabilities to release scenarios is, in part, a subjective process because of the uncertainties in extrapolating limited scientific and historical knowledge to periods up to 10,000 years. However, the probabilities assigned must be shown to be reasonable on the basis of current knowledge.

Specific Aspects of Mathematical Models

The mathematical models used in performance assessment are representations of conceptual models of the physical system. The degree of representation is significant because the misapplication of mathematical models may produce misleading or erroneous results. The use of mathematical models must be justified by the site data. In systems where uncertainty is introduced through the use of phenomenologically untestable models, bounding approaches may be used. The extent to which bounding approaches can be justified and demonstrated as being conservative will affect the reliance that can be placed on the calculations of performance.

Although benchmarking, verification, documentation, and validation of the predictive computer codes will not eliminate uncertainties about the applications of computer codes, they will contribute to the demonstration of the reliability of the codes in making these predictions. This reliability will add credence to the demonstration of compliance with the performance objectives. The NRC staff has issued guidance on suggested formats for and content of computer code documentation (Ref. 11). Additional informal guidance on code verification and benchmarking is available through review of the NRC code-benchmarking project (e.g., see Refs. 12, 13, and 14).

To the extent practicable, the NRC staff intends, before licensing begins, to determine whether the numerical models and codes used by DOE are computationally sound and physically reasonable. This evaluation will cover the codes themselves and a comparison of the results from benchmarking problems with the results from the use of other similar codes. It is, therefore, important that DOE complete the documentation of these codes rapidly and be prepared either to release them or to exercise them in support of the NRC review effort.

DOE/NRC PRELICENSING INTERACTION

The development of a high-level waste repository is a first-of-a-kind activity. The project presents important concerns about public health and safety, and it

may be the largest civil construction activity ever undertaken in this country. It represents major commitments of public funds and privately derived funds. Therefore, it is important that the job be done right--the first time.

By understanding between the two agencies, and with the implicit approval of the Congress, DOE and NRC are in a consultative mode during the present, prelicensing period. This means that the two agencies interact on matters that relate to licensing of a repository. The matters that are under discussion include questions about the application of 10 CFR 60 to ongoing DOE activities, the types of information that will be needed at licensing time, appropriate approaches to site characterization, and types of testing needed to answer licensing questions. The modes of interaction are numerous and varied and include public meetings, such as this GAIN 84 Symposium; NRC comments on DOE programmatic documents, such as the July 31, 1984, comments on the DOE Mission Plan (Ref. 6); NRC technical positions, such as "Hydrologic Testing Strategy for the Basalt Waste Isolation Project" (Ref. 15); and notes on DOE/NRC technical meetings, such as the NRC/DOE Geology Workshop (Ref. 16) and the NRC/DOE Hydrology Data Orientation and Data Review (Ref. 17).

It is important to note that all these technical interactions are being carried out in full public view. This permits the public, including the interested technical and the political communities, to be aware of what is going on in the prelicensing process and to provide input. Consultation meetings are open to members of the public as observers. [NRC provides, by telephone, a recorded notification of such meetings; the number is 1-800-368-5642, ext. 79002, or 427-9002 for Washington, D.C. area callers. DOE provides a similar service; the number is 800-368-2235, or 800-492-4610 for Maryland callers. The documents arising from all consultative meetings, such as meeting notes, are placed in NRC's public document rooms.]

CONCLUSION

The long-term management of high-level radioactive waste is a national imperative of the highest order. It calls for the best skills and talents of the scientific and technical community; of political institutions at all levels --national, State, Indian tribal, and local; and of the Government agencies responsible for the development and regulation of a high-level waste repository. Success will be more likely, and less costly, if these skills and talents are fused in a constructive fashion.

This paper deals with some facets of licensing information needs that are relevant to geotechnical testing. The NRC staff expects to continue its interactions with DOE, the public, and the technical community so that a common

understanding can be reached about the requirements that will be imposed during licensing consideration of a high-level waste repository.

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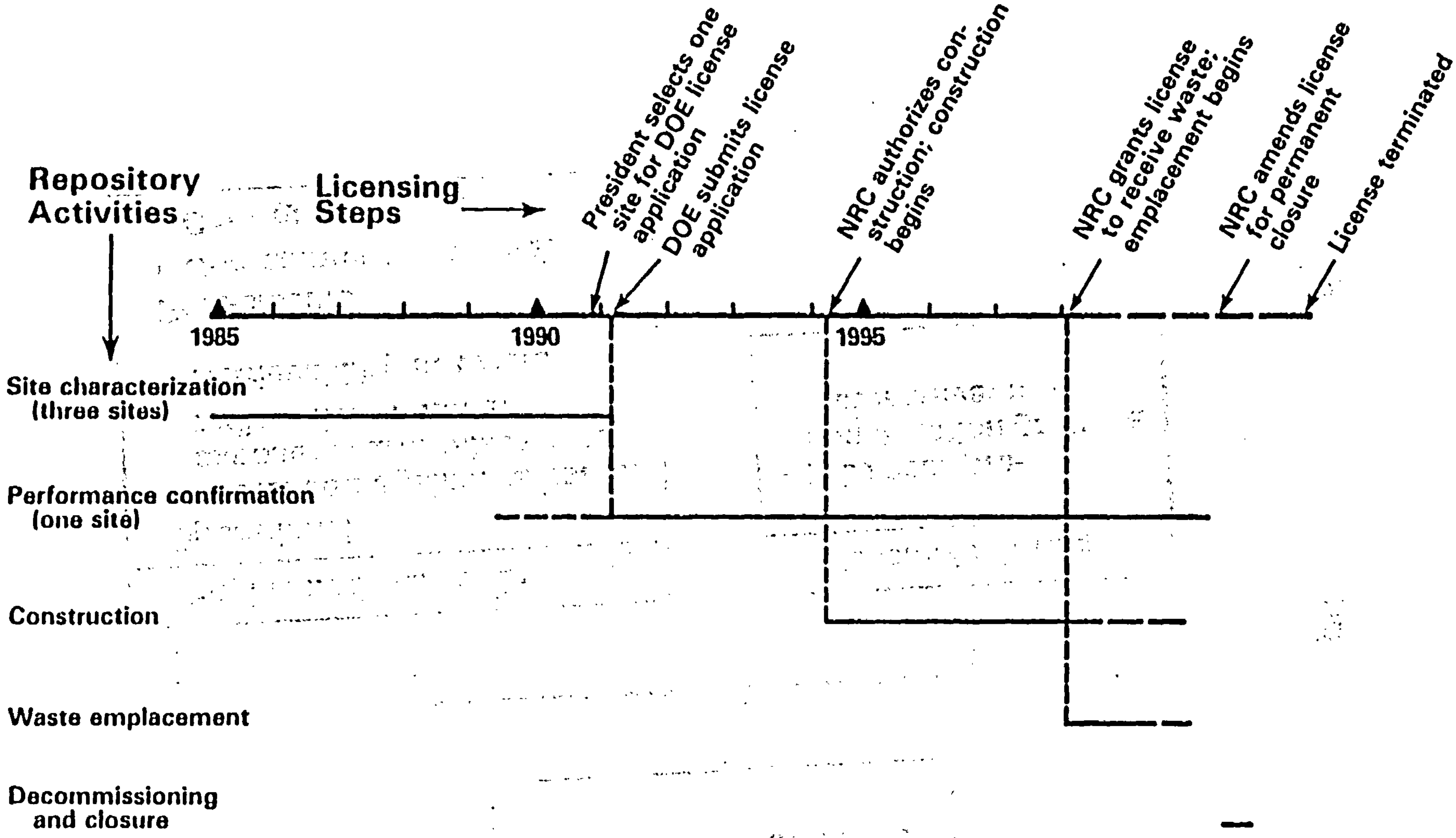
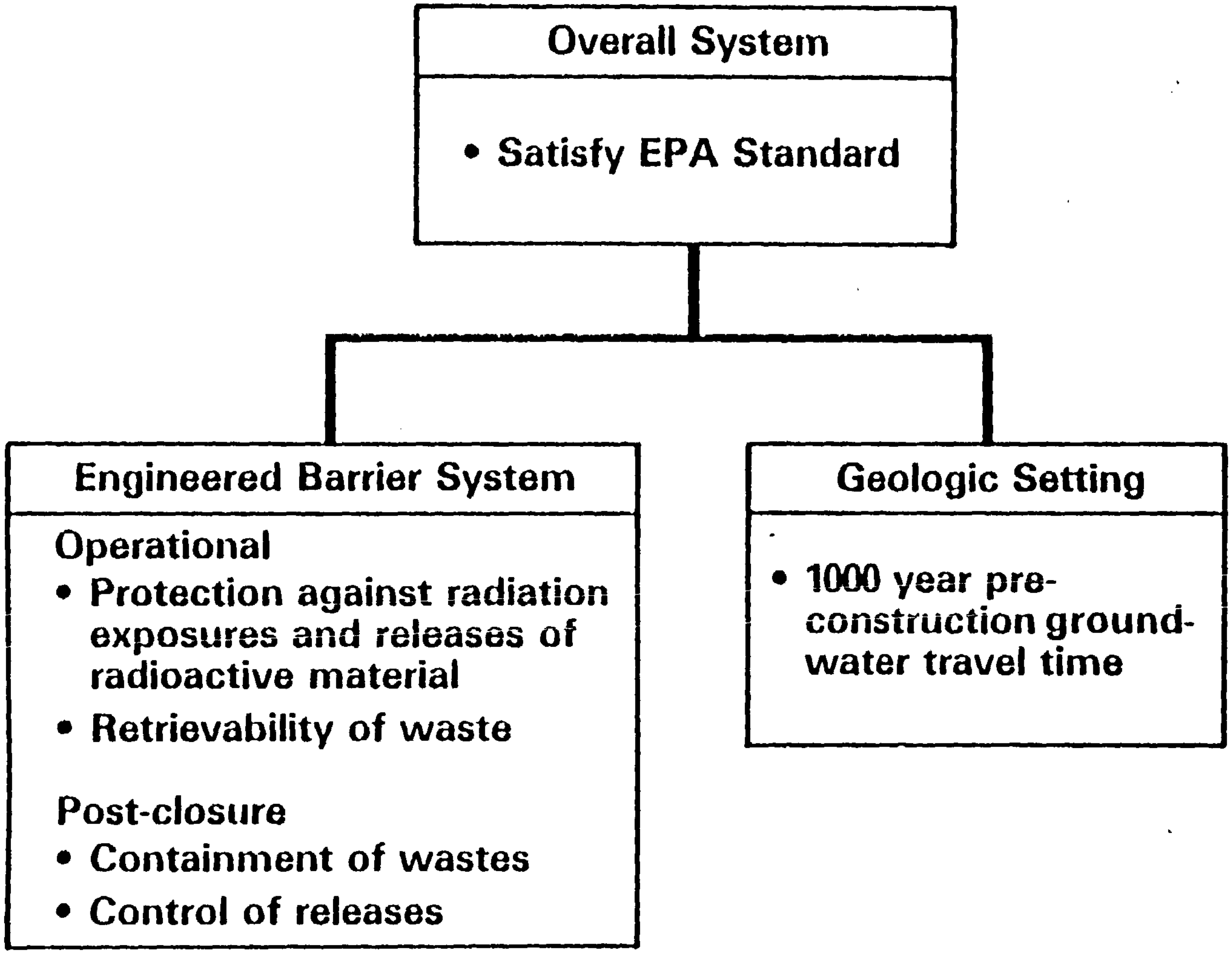
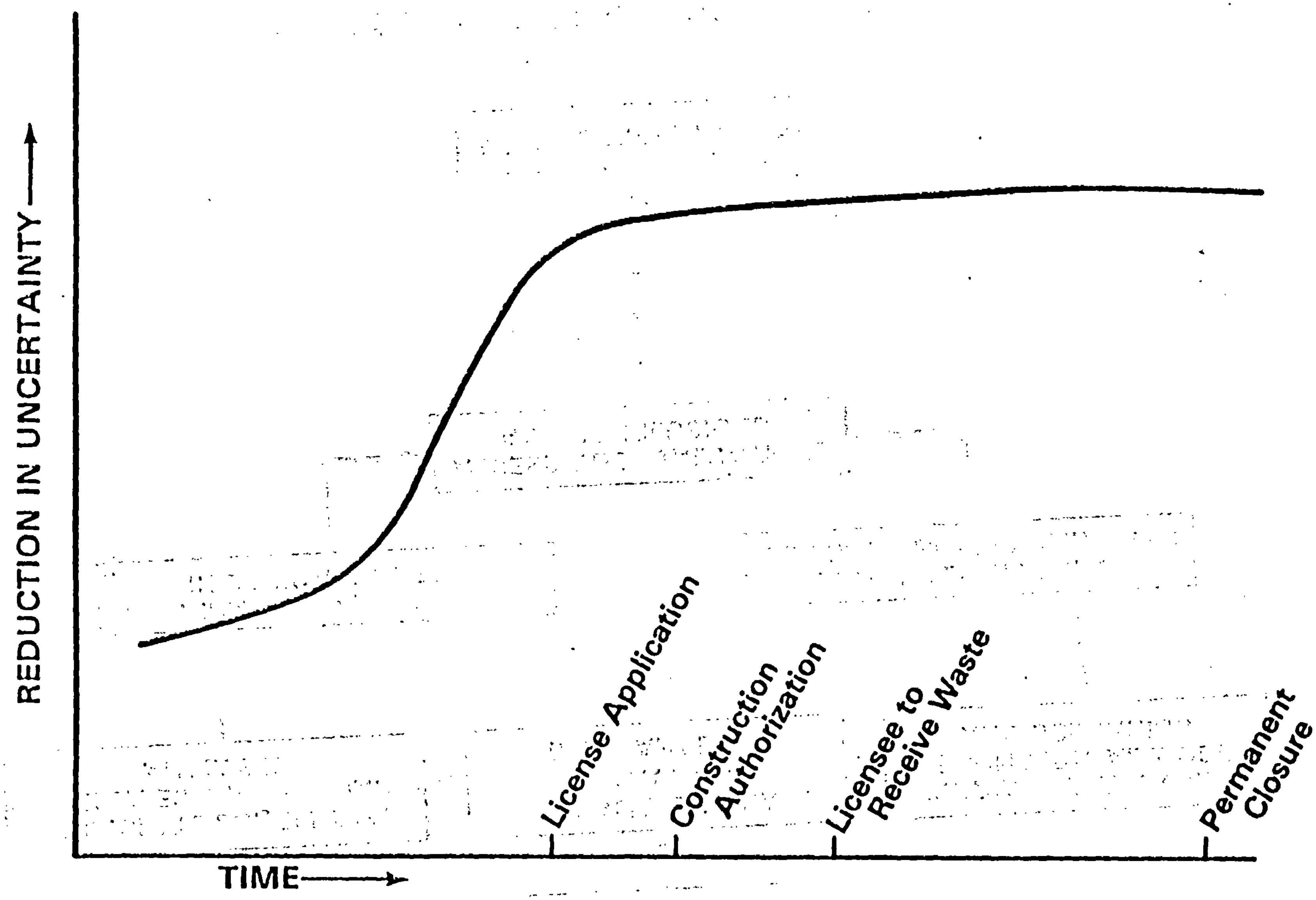


LICENSING STEPS AND REPOSITORY ACTIVITIES
FIGURE 1

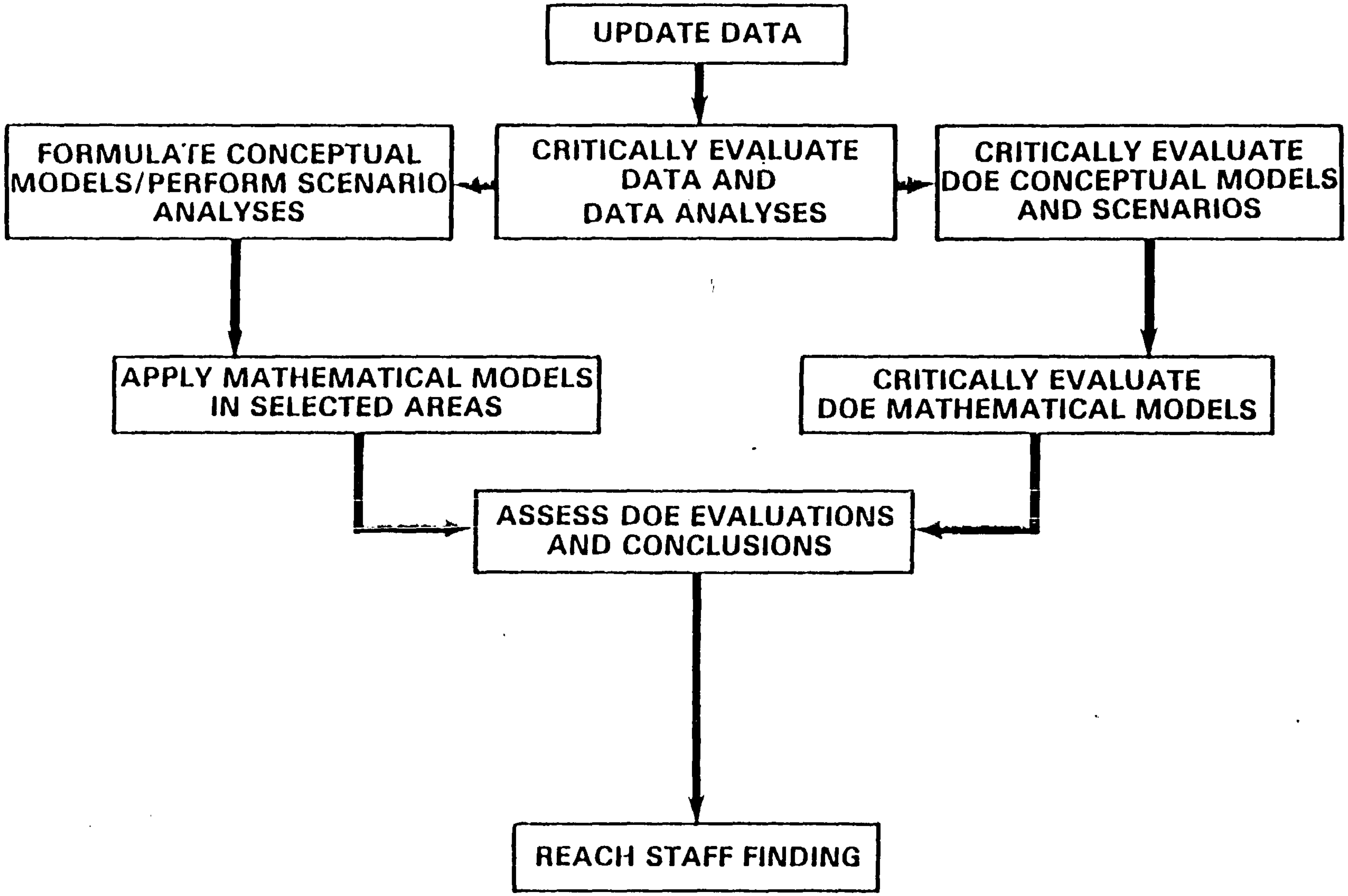


PERFORMANCE OBJECTIVES
FIGURE 2



NOTE: Not to scale

REDUCTION IN UNCERTAINTY
FIGURE 3



GENERAL PROCESS FOR NRC STAFF ASSESSMENTS OF A LICENSE APPLICATION
FIGURE 4