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

NOTE TO: Margaret Federline

FROM: Joseph Holonich

SUBJECT: OFFICE OF RESEARCH PROGRAM PLAN

Attached is the HLPD review of the first two chapters of the Office of Research Program Plan. HLPD has coordinated this review with HLHP (Rex Wescott) and HLGE (Ron Ballard) as well as with Mel Silberberg.

A copy of the review, consisting of a re-write of Chapter One, a partial re-write of Chapter Two and a mark-up of the remainder of Chapter Two were faxed to Mel Silberberg on March 12, 1993. These changes were discussed with Dr. Slberberg on March 10.

If you have any comments, please call Paul Prestholt on 504-3810.

Joe Holonich

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Enclosure:
As stated

414.4.1

1.1 Background

The United States as well as other countries facing the question of how to handle high-level nuclear waste has decided that the most appropriate means of disposal is in a deep geologic repository. This approach has become generally accepted as the method that best addresses the problems of high-level waste disposal because it is believed that this way is the most technically viable. Deep geologic disposal was presented first by the U.S. Department of Energy (DOE) in its Environmental Impact Statement issued in October 1980, and in its Record of Decision for disposal of commercially-generated radioactive waste issued in May 1981. Later in 1984, the U.S. Nuclear Regulatory Commission issued its first waste confidence decision related to the storage and disposal of high-level radioactive waste. In that decision, one of NRC's five findings was that there was reasonable assurance that safe disposal of high-level waste and spent fuel in a mined geologic repository was technically feasible. Although the decision was revised in 1990, the NRC still maintained that deep geologic disposal was technically feasible.

The Nuclear Waste Policy Act, enacted in 1982, endorsed the DOE decision to pursue deep geologic disposal. It established milestones and schedules for the development of two repositories, one to be sited in the west by 1998, the other in the east at a later date. The Act required DOE to conduct in situ tests of three potential sites and recommend one of the three to the President and Congress for development as a repository. In 1987, Congress enacted the Nuclear Waste Policy Amendments Act which suspended site investigation activities at all sites other than the Yucca Mountain site, and suspended all activities related to a second repository.

The storage and disposal of high-level nuclear waste, including spent nuclear fuel, is the responsibility of the Department of Energy (DOE). These responsibilities are given to DOE through a number of actions including the Nuclear Waste Policy Act of 1982. Under the Act, DOE is assigned the responsibility for constructing and operating a high-level waste repository. In the area of high-level waste disposal, two other Federal agencies, the Nuclear Regulatory Commission and the Environmental Protection Agency (EPA), are also assigned responsibilities for the disposal of high-level waste in the U.S. The NRC is responsible for licensing and regulating the receipt and possession of high-level waste. Its requirements governing the disposal of high-level nuclear waste in a geologic repository are contained in 10 CFR Part 60, and cover pre-licensing activities, construction authorization, receipt and possession of spent fuel or high-level waste, decommissioning and termination of license. With respect to EPA, its responsibilities are to establish generally applicable standards governing releases of radioactivity. These regulations are found in 40 CFR Part 191, and set the environmental standards for the management and disposal of transuranic and high-level nuclear waste. NRC must promulgate regulations that are not inconsistent

with the standards promulgated by EPA.

Within NRC, the responsibility for reviewing DOE's HLW license application lies with the Division of High-Level Waste Management (HLWM) of the Office of Nuclear Material Safety and Safeguards (NMSS). The Waste Management Branch (WMB) in the Division of Regulatory Applications of the Office of Nuclear Regulatory Research (RES), under whose auspices this plan was written, conducts a program of HLW research to support HLWM's mission to protect the public health and safety from radiological hazards of HLW disposal. Both HLWM and WMB use contractual assistance to carry out their HLW regulatory obligations. Since October 1987, the prime NRC HLW contractor has been the Center for Nuclear Waste Regulatory Analyses (CNWRA) at the Southwest Research Institute in San Antonio, TX. Some limited HLW research is done outside CNWRA in accordance with criteria discussed in references [R300] and [R301].

Figure 1 shows the hierarchy of the HLW regulatory criteria that serve as the basis for the HLW research program. The objective of the NRC and EPA regulations is to ensure that health and safety is protected. The requirements in 10 CFR Part 60 demand acceptable total system performance. Part 60 has performance objectives, design criteria, and siting criteria that are focused upon either the engineered system or the geologic system. The goal of the containment and controlled release performance objectives, and the design of the groundwater travel time performance objective and the siting criteria is to ensure acceptable performance of the geologic system. Acceptable performance for containment, controlled release, and groundwater flow is defined by the performance objectives for multiple barriers. Hydrogeological, geochemical, and geological siting criteria and engineered system design criteria provide specific technical requirements and considerations that DOE must meet and consider in demonstrating compliance with the above requirements and goals.

In figure 1 Change CDS to review strategy and CDR to review method and acceptance criteria

1.2 Overview of the Plan

The primary purpose of this plan is to provide a blueprint for developing effective regulatory research that supports the objectives of the NRC's high-level waste program. It is intended to present the type of research being conducted, and show how this research supports the needs of NMSS. Overall, the plan provides the User Needs identified by NMSS, a description of the research being conducted, and a presentation of how that research supports the NMSS User Needs. Based on 10 CFR Par 60, the research program presented in this report is divided into seven parts. These are: (1) controlled release; (2) containment; (3) engineered system; (4) hydrology (and groundwater travel time); (5) geochemistry; (6) geology; and (7) performance assessment.

The incorpoation of the HLWM User Needs into this plan is serving the important objective of assuring that the NRC HLW research is integated with HLWM's pre-licensing and licensing activities and the technical assistance provided to it by the CNWRA. Development of this plan has required close cooperation between the WMB and HLWM staffs. The process of development, review, and publication of this plan documents the NRC HLW research program and serves both as a means of obtaining policy-level review of the NRC's policy document, the Five-Year Plan. Furthermore, this process improves communication between NRC's researchers and program office, and helps to strengthen the NRC HLW research program.

The formulation and drafting of this plan and the User Need statement, Appendix B, have proceeded concurrently with the development of HLW research projects at the CNWRA and other contractors. One of the main ways that development of this plan helps achieve the objective of effective regulatory research is by gaining review of the HLW research program. This plan has benefitted from several reviews by RES' advisory committee, the Nuclear Safety Research Review Committee (NSRRC), and the Commission's Advisory Committee on Nuclear Waste (ACNW). The NSRRC reviews brought out the major need to develop a program in geology to address problems of volcanism and tectonics. The ACNW review helped bring about a better integration with the HLWM licensing program. The strategy for review of the HLW research program plan and specific research areas is presented in Section -----.

1.4 Purpose of HLW Research

The purpose of the NRC HLW research program is to support NRC's licensing review and the development, modification, and implementation of regulations, and regulatory guidance. The primary regulatory bases for the research program are the requirements of 10 CFR Part 60. As mandated by NWPA, DOE will conduct site characterization activities (including field and laboratory studies) and prepare a license application to demonstrate compliance with 10 CFR Part 60. NWPA mandates that NRC

review DOE's license application, and make a construction authorization decision. Because of these different statutory responsibilities, NRC's research activities are different from those of DOE, and are consistent with its (NRC's) licensing role. Accordingly, it is appropriate for the staff to conduct research for any one of the following reasons [R302];

(1) develop the licensing tools and technical basis necessary to judge the adequacy of DOE's license application;

(2) ensure a sufficient independent understanding of the basic physical processes taking place at the geologic repository; and

(3) maintain an independent, but limited, confirmatory research capability, under NRC auspices.

Research required for an independent understanding of basic physical processes that may affect HLW repository performance (research reason 2) involves investigations on topics having major technical uncertainty of critical regulatory importance. The NRC staff makes full use of DOE site characterization data and analyses in developing its independent understanding. The NRC research is limited to consideration of health-and-safety related issues, as compared to DOE investigations, which must consider a broad range of topics, including site characterization, repository design and construction, repository operation, transportation, closure, and cost.

There are unique planning needs for NRC's HLW research. Because a repository for HLW has never been constructed, information needed to support NRC's licensing decisions about HLW disposal has no direct experience as a base. Even though DOE will be the primary source of information for the proposed site and technical analyses to defend its license application, the NRC needs independent information to confirm the correctness of DOE's data base and analyses. The information is needed in order to reduce uncertainty (i.e. provide a technical basis for confidence) in making HLW licensing decisions. The NRC HLW research program is endeavoring to assemble as much of this independent technical basis as possible so that the NRC staff will be able to use it in its licensing review.

2. Strategy

2.1 Strategy

2.1.1 Overall Program Strategies

Although NRC has licensed many reactors and numerous materials users, the HLW repository is a unique, first-of-a-kind facility. Therefore, the NRC cannot rely on prototypes, and previous experience in conducting reviews may have limited use. Plus, the NRC had to (and continues to) create a regulatory and licensing framework where none existed. This means refining its regulations, developing guidance, developing review and technical analysis capabilities, and conducting research.

In general, the overall strategy of the NRC's HLW program is found in a number of different documents. These include the Five-Year Plan, which establishes program commitments based on resources budgeted. In addition, there are the existing regulatory strategy documents such as SECY-88-285 [R160], and its updates SECY-90-201 [R298] and SECY-91-225 [R299]. These are high-level planning documents that examine the relevant regulations and guidance to determine whether the proper mix is in place, and to identify any proposed rulemakings, and Staff Technical Positions.

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Complementing the regulatory strategies is the HLWM's Overall Review Strategy (ORS). Its primary purpose is to give general guidance to the NRC staff in conducting its license application and pre-license application reviews, and describes the development of the NRC staff's review capability. The information developed through implementation of the ORS guides the specific planning for reviews, review capability development, and research to support the annual Five-Year Plan and budget preparation. In addition, the ORS will improve the identification, prioritization, and integration of NMSS and RES activities. When the ORS and the regulatory strategies discussed above are coupled together, a consistent planning basis for the NRC HLW program for licensing a repository is provided.

2.1.2 License Application Review Strategy

In general, the ORS addresses both the staff's pre-licensing reviews and its license application review activities up to, and including, the completion of the Safety Evaluation Report. It guides the preparation of more specific review strategies for each of the requirements of 10 CFR Part 60. These specific review strategies will be included in the License Application Review Plan (LARP). Each Individual Review Plan within the LARP will be self standing and contain 1) the applicable regulatory requirements, 2) a review strategy, 3) interfaces for conducting the review, 4) review methods to be used by the staff, 5) acceptance criteria for determining compliance with the regulations, and 6) example evaluation findings that will help establish the objectives of the review. Of particular importance to the NRC research program are

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the review strategies, which will be used to guide the NRC staff on the level of review that should be conducted for that individual review plan.

The basic review strategy consists of conducting a complete compliance review of the broad level of information in the license application and more detailed reviews on an audit basis (in selected areas) to determine if the detailed information supports DOE's demonstrations in the license application. This strategy can be envisioned as a vertical slice through a program area from broad to very specific levels using the results of staff investigations. These investigations might include analyses where the staff uses the results of its own performance assessments by applying either available numerical models, models it has developed independently, or research results. In addition, it helps to prioritize the review by identifying the higher priority areas that will receive more attention by the staff. Areas selected for detailed review will be primarily focused on technical uncertainties most important to repository performance.

This strategy also recognizes that, because of the nature and complexities of the repository program, some flexibility must be maintained while conducting the staff's compliance reviews. If the staff finds during its review of the application that it needs to go to a greater depth regardless of whether a technical uncertainty has been identified, it will do so. Thus, this review strategy not only ensures that the NRC will conduct a complete review at a broad level, but also directs the staff to focus detailed attention on those areas most important to performance and that will likely be the areas most difficult to consider in licensing.

It should be emphasized that the burden is on DOE to provide the data and assessments to support its performance assessments in the license application. In most cases, the staff will rely on DOE data and analyses, independently reviewed by the staff, as input to the staff's performance assessments. In addition, the results of staff research might also be used to either confirm some of DOE's results or simply to gain an independent understanding of a condition or process to enhance the staff's ability to conduct detailed reviews.

2.1.3 RES/NMSS Staff Coordination

Procedures and mechanisms are in place between WMB and HLWM for a range of coordination activities that bring the user office and the research office in close programmatic harmony. In Appendix C the procedures for coordination are discussed in some detail. A key mechanism for program coordination is through integration of research into the licensing strategy. This is discussed further in Section 2.2.

2.2.1 Integration of the HLW Research and Licensing Program

As a first step in preparing review strategies, the staff will be identifying any key technical uncertainties (KTUs) related to compliance with 10 CFR Part 60. KTUs are uncertainties which poses a high risk of noncompliance with the performance objectives of 10 CFR Part 60. Depending on the importance of the KTU, the staff may choose a number of different ways to address its reduction by DOE. In all cases, it would develop acceptance criteria for the staff to use in reviewing DOE's treatment of the uncertainty. However, in

some cases, it could also issue a Staff Technical Position giving guidance to DOE on what DOE can do to demonstrate compliance with the appropriate requirements for those KTUs requiring development of an independent database and/or analysis methods. The staff could also identify research that it would conduct to support the reduction of the uncertainty, or it could conduct its own technical analysis of the requirement using either computer codes generated by other organizations or codes developed directly by the NRC staff.

In addition to identifying the type of work the staff must do to address an identified technical uncertainty, the NRC staff will also use this information to determine the depth of review it will conduct in evaluating that section of DOE's License Application. This is not to say that the staff will be less thorough in its review of the entire application. On the contrary, the NRC staff will be conducting a safety review of all sections of DOE's application where compliance is necessary to make a safety determination for a construction authorization as defined in 10 CFR 60.31(a). These include those requirements embodied in 10 CFR Part 60, Subparts E, G, H, and I; but for those areas where a technical uncertainty exists, the staff will conduct a more detailed safety review. However, as stated earlier, if the staff finds during its review of the application that it needs to go to a greater depth regardless of whether a KTU has been identified, it will do so.

After NMSS determines the KTUs, it identifies which it believes needs to be reduced through research. These are then developed into User Needs that are provided to RES, and serve as the basis for RES' preparation of its program. The research needs identified as a result of the review strategy development will be compared to the ongoing research program and necessary adjustments will be made. As research work progresses, the staff will evaluate the results to determine if additional research is needed to satisfy review needs.

The proposed research can develop an independent understanding of basic processes that will support the development of licensing tools such as models and codes. In addition, it can provide data and other information that will contribute to the technical basis necessary for the NRC staff to judge the adequacy of the license application. Plus research can also provide limited confirmatory information.

For the results to be useful to NMSS, the identified research must be directed at addressing and supporting the staff's review of DOE's reduction of KTUs identified by NMSS in its preparation of the review strategy. Also, the results must be available in a timely manner throughout the pre-licensing phase of the program so that the staff can use these results in its prelicensing reviews. Their final use will be to allow NMSS to determine that the KTU has been quantitatively addressed by DOE such that it is no longer a concern, or the research results will allow NMSS to develop the acceptance criteria or review methods necessary to determine if DOE has acceptability demonstrated compliance with 10 CFR Part 60. In either case, NMSS and RES must work together to ensure that ongoing and planned research are supporting the review of KTUs identified through the development of review strategies. Thus, the research results feed directly into the preparation of the individual review plans of the LARP.

It is important to note that there are other parts of the NRC's program that help support preparation of the individual review plans. For example, the staff has an extensive effort underway in the development of its capability to conduct iterative performance assessments. These performance assessment methods will eventually become the review methods and help develop the acceptance criteria for individual review plans. The work being completed under this program will also either confirm the KTUs already identified by the staff that are related to compliance with the regulation or help identify additional KTUs. Thus, the preparation of the review strategies for the individual review plans are directly supported by the staff's iterative performance assessment capability.

Similarly, the NRC staff has a program where it is developing analysis methods it will use to review DOE's ongoing site characterization and design work. Examples of these are tectonic models, waste package performance, and thermal loading of the repository. When these methods are complete, they, like the iterative performance assessment capability, will become the review methods and will help develop the acceptance criteria of the License Application Review Plan. In addition, iterative performance assessment and analysis methods along with the License Application Review Plan all help the staff identify interfaces in its technical review areas, plus help ensure that research work being conducted by the staff is well integrated and supports the licensing needs of the program. Figure 2 shows the research program regulation program integration.

Figure 2

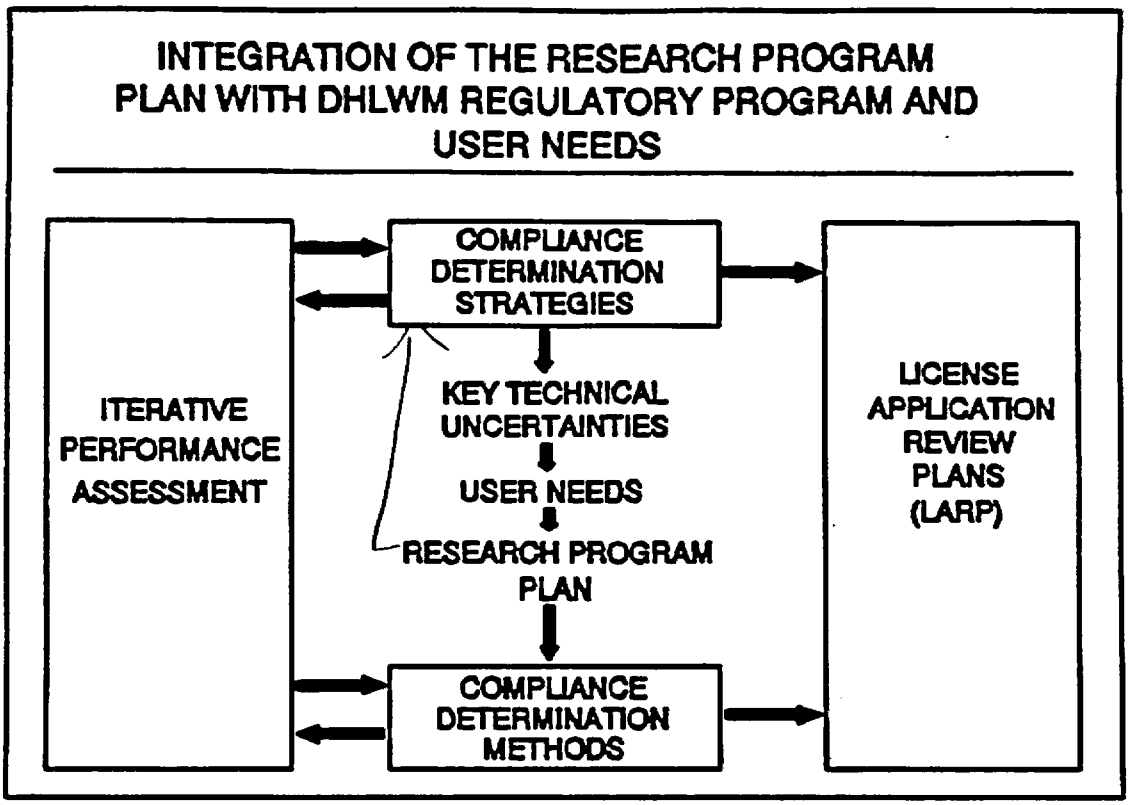


Figure 2: RESEARCH PROGRAM - REGULATORY PROGRAM INTEGRATION

IRA influences and is influenced by CDS and CDM development. IPA contributes to the identification and refinement of specific technical uncertainties. IPA provides an assessment of importance/priority of uncertainties by means of sensitivity analyses and focuses on the impacts of performance.

~~CDS and CDM~~ development is iterating ~~based on~~ results of IPA and evaluation of the research program results. ~~CDS development~~ is scheduled for ~~initial completion of~~ FY 93 and ~~CDM~~ development is scheduled for completion during FY 94-97. ~~These products and processes all influence each other are designed for iteration and refinements.~~

2.2.2 Research Program and Technical Assistance Program Integration

In section 2.2.1 we described the integration of the HLW research and HLW licensing programs through the LA review process. The LA review process is only one of the HLWM program activities which also includes a HLW Technical Assistance (TA) Program being carried out through the CNWRA. The integration of HLW research studies and HLW TA studies occurs at the CNWRA on a continuous basis.

(The remainder of this section is still under development by WMB and HLWM.)

2.2.3 Integration Review and Updating

As described in Appendix C there is a mechanism for reviewing and updating user

needs, approximately on an annual basis, based upon many different sources of information. These information sources include: the annual updates to the ~~CDSs~~ based upon research results, IPA or results from the DOE program; additional and/or revised user needs from changes in ~~CDSs~~.

At this point we are in a transition from user needs developed earlier in the program (several years ago) and the user needs which would evolve from the LARP process, ~~e.g. CDSs and KTUs~~). Only some of the ~~CDSs~~ have been completed to date. Completed ~~CDSs~~ and the KTUs derived therefrom ~~and~~ being compared with the existing user needs (Appendix B) for confirmation that these needs meet the needs identified in the strategy for resolving a KTU. The RES/NMSS staff anticipates that the current user needs and the related research program will meet the needs of LARP when completed in FY 94. In these cases where user needs are found to change, appropriate changes will be made in the research program

2.3 Research Strategy

2.3.1 Overall Approach and Focus

NRC HLW research is focused on key technical uncertainties in accord with the strategy discussed in Sections 2.1 and 2.2.

A unique aspect of HLW licensing is that, depending on the performance objective, it involves the assessment of performance of engineered and natural systems over time scales ranging from 300 to 1,000 years and greater for the engineered system to at least 10,000 years for the geologic system. Engineered systems are generally designed to last for much shorter time periods. ~~The only true exceptions are the pyramids of Egypt and Mexico that were designed for religious purposes~~. There is no established engineering basis for predicting performance ~~on time scales of~~ over 300 to 1,000 years ~~and greater~~. Likewise, although earth scientists describe and understand processes that occur over thousands, millions, and hundreds of millions of years, there is not an established scientific basis for predicting the performance of the repository system. The NRC must decide, using informed scientific and engineering judgment, what approaches are acceptable for assessing the long-term performance of the engineered and geologic systems. Among the approaches to address the time issue are ~~to develop~~ development accelerated testing protocols or use of natural analogues, ~~i.e. natural systems in which the effect of the operation of the important processes over thousands of years can be studied~~. Because long-term performance assessment is crucial to licensing, a major part of the HLW research is directly related to this issue. The single most important aspect of this work is the development of a sound scientific basis for the use of available data.

NRC HLW research does not develop data specific to the Yucca Mountain site unless there are ~~particular DOE models or data that are being assessed because of a specific major~~ licensing concern of the NRC staff. The NRC HLW research focuses on technical areas of major uncertainty and significance with respect to the performance objectives and siting and design criteria of 10 CFR Part 60. This research generally involves studies of processes and mechanisms that could occur at Yucca Mountain without using data specific to the Yucca Mountain site. Data developed by NRC are generally used to understand key processes governing HLW repository performance and to test measurement methods, concepts, theories, and

models. Site-specific data may be developed for these confirmatory purposes if needed. The research is carried out through laboratory and field experiments and modeling to understand and assess relevant phenomena and processes important to performance.

2.3.2 Prioritization.

2.3.2.1 Evolution of Current Program.

The present form of the NRC HLW research program is a direct result of Congressional and NRC policy decisions made in FY 1987. The first of these decisions was the Congressional direction to limit site investigations for a high-level waste repository to Yucca Mountain. The second decision was the NRC selection of a prime contractor for most of its high-level waste technical assistance and research work. Both of these actions required a major restructuring of the research program.

The response was taken in two stages. The first action was to review all ongoing work to determine if it would apply to the proposed Yucca Mountain site. Decisions were made on a case-by-case basis to retain, redirect, closeout in an orderly manner or terminate. Of prime concern was the relevance of the work to regulatory analyses to support performance reviews of the proposed site as required by 10CFR60. The second action was to develop a plan for transfer of research work to the CNWRA. This latter action was further constrained by the assumption that the CNWRA would need a stable funding base in order to hire the high quality scientific staff that would be needed to support the NRC regulatory program. The remaining research contract mix was examined in the context of these two constraints with additional attention given to unique characteristics of the Yucca Mountain site. Evident from the very first days of this process was the active tectonic setting which would eventually require a fundamental understanding of the processes controlling the volcanic and seismic features of the area in order to assess the effects of disruptive events on simulations of repository performance.

Critical ongoing work that was near completion such as the performance assessment methodology development at SNL was redirected to allow an orderly transition to the CNWRA after completion of the development and documentation stage. Drawing on experience gained in the earlier BWIP reviews and those user needs which were still appropriate, information and expertise needed to support evaluation of routine repository performance for Yucca Mountain were identified and given the first priority. Stability and quality of the CNWRA staff were superimposed as policy constraints and the phase-in plan was developed considering the timing needed for orderly termination of projects such as the SNL PA work.

The program which took shape had a surface structure very similar to the one that had evolved for the pre-Yucca Mountain program with the exception of a strong emphasis on geology (i.e. the geologic processes controlling seismic and volcanic events). Internally there were other significant differences because the geochemistry, rock mechanics and sealing work had to deal with a tuff host rock, and the hydrology program had to focus on flow in unsaturated, fractured rock instead of a saturated system. Noting this similarity of structure and expertise it also became clear that thought should be given at the CNWRA to look at its

staff as centers of excellence in these topical areas with research teams having complementary expertise and experience. Eventually a systematic planning effort was begun which resulted in the structure described in detail in Section 1.2 of this document.

2.3.2.2 Future Strategy

As the CNWRA TA program evolved it was tasked by NMSS to develop a systematic assessment of the existing regulatory and scientific basis for the HLW regulatory program and apply this to detect ~~weaknesses~~ which needed to be addressed. It was felt that this systematic assessment would provide insights applicable to the research planning process. Concurrently, RES, NMSS and CNWRA staff were building up a capability to conduct PA analyses. With conscious recognition of its limitations, it was noted that this capability, as it evolved, would become capable of providing additional insights into the planning and prioritization efforts. The latest efforts (described earlier in Section 2.2) have resulted in an integration of the license application review strategy, user need development, and research planning effort into a fully interactive process which will be sensitive to developments in the repository program as they occur.

Central to the process is the coordination program presented in Appendix C. This program describes the annual review of user needs; periodic ~~on-site~~ research project reviews; the formal, interactive project development and review process for new work; and biannual coordinated program reviews for research areas (including relevant LLW research contractors). To the greatest extent practicable both NMSS and RES will optimize staff participation, as appropriate, in all phases of this coordination program in order to ~~assure~~ the most current knowledge of both the state of technology and progress in the DOE program.

In the final analysis this coordination process defines the environment in which prioritization decisions will be made. It will remain a qualitative process ~~where the~~ best technical recommendations of the staff based on professional judgement, ~~SRA~~, PA and the integrated coordination program are weighed against the availability of resources, programmatic constraints such as long term stability at the CNWRA, and DOE schedules for repository development.

2.3.3 Confidence Building (a.k.a. Validation)

The reason for research in HLW is to provide a technical basis for licensing decisions. In many cases this will ~~reduce to whether~~ decision makers have confidence in the staff analyses and model simulations which are presented in support of ~~those~~ licensing decisions.

Building the basis for confidence can be looked on as an iterative process containing several distinct steps. First the range of conditions, processes or events which affect the decision must be defined. Once the problem has been defined an approach to the analysis must be prepared, often a conceptual system model. The conceptual model is then followed by a computer simulation model which conforms to the conceptual model but may be limited by key assumptions to the expected range of conditions. The next step is to find data which are independent of this model development process. Independence is necessary because

the modeling process can build biases into the model which are not detectable unless the model is applied to another set of data ~~to which it should also apply~~.

This is the fundamental problem with models built solely on an understanding of site data. If that site is driven beyond the range of conditions used to define the model, there is no assurance that the model simulation will represent reality. The only way to gain this assurance is to collect representative data that ~~sample the range of~~ potential future realizations of the system and test the models by applying them to these data sets. Implementing this process in an iterative fashion should ~~allow convergence to~~ confidence and sound licensing decisions. It should be recognized that if this strategy is not tempered with reason it can place a severe burden on resources because of the expense of adequately characterizing and understanding ~~field sites for studying~~ geologic processes. However, if the common understanding within the international community is allowed to prevail, a reasoned approach to sampling a range of possible realities is possible, especially if international cooperation and shared funding of ~~especially~~ relevant investigations is pursued. (The use of international cooperative programs such as INTRAVAL and DECOVALEX to apply models to data from these programs is also a highly effective way of pooling knowledge and experience.)

2.3.4 The Role of Natural Analogues

The fundamental weakness in the confidence building process described above is the wide range of conditions which may exist in the repository over the long period of time for which the decision makers must have confidence in the reality of the model simulations. Figure 3 shows the magnitude of this problem by superimposing the range of data available from laboratory and real time field

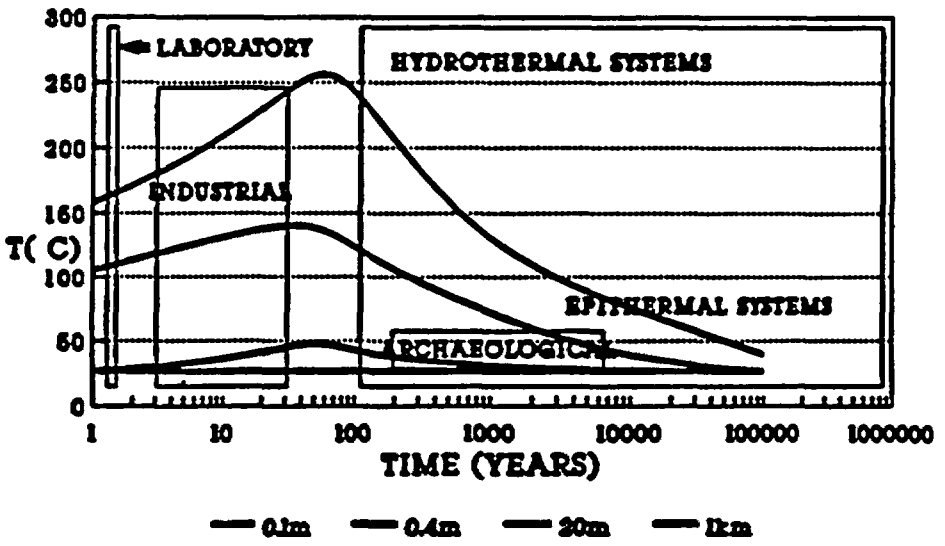


Figure 3: TIME-TEMPERATURE VERSUS TYPES OF ANALOGUES

experiments on the time temperature curve expected at various distances from a

waste package in the repository. Conventional experimental work can handle the temperature ranges but is incapable of handling the time span involved. A third factor, physical size, is also difficult to handle for slow moving groundwater systems.

like time periods

The severe limitation of conventional data sources has led to the focus of attention on natural systems where similar processes may have occurred over ~~geologic or historic times.~~ The additional areas labeled on Figure 3 show where general classes of "natural analogue" studies can provide information in the confidence building process. While this figure makes a strong connection to the high temperature planned for the US repository, the strategy of investigating expected processes and events in natural systems where they have been operating over geologic times is an approach being used widely in the international waste management community.

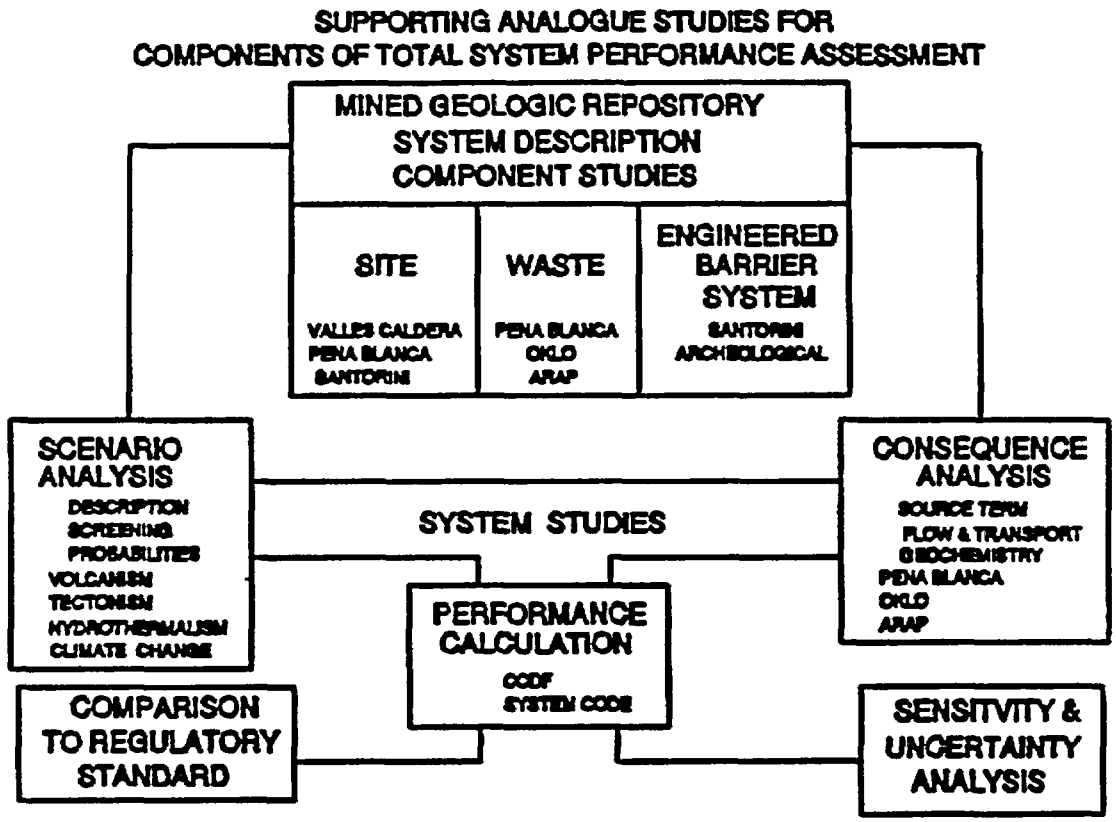


Figure 4: APPLICATION OF NATURAL ANALOGUES

In 1983 a number of geo-scientists from countries with nuclear power programs met to discuss the use of natural analogues to help understand the nuclear waste disposal process. This meeting was the first of what is now the CEC sponsored Natural Analogue Working Group. The meetings since that first effort have shown an evolution in the depth and diversity of thought on the use of natural analogues. This evolution is reflected in the NRC natural analogue program described in Figure 4. This conceptualization of the review process includes indications of where specific natural analogue research projects may help extend

our understanding of the long term or high temperature performance of the HLW repository.

The detailed research program presented in Appendix A ~~mentions~~ natural analogue projects in most areas. In almost all cases these projects supplement laboratory or real time field experiments to add another dimension in time, temperature or spatial scale and thus extend the domain over which performance assessment models can be tested. These programs are not and can not be expected to be exhaustive. Resources must be applied within reason to attain a level of confidence that will allow regulatory decisions to be made. The rule of reason to be applied must temper accuracy with the magnitude of expected impacts and the need to come to closure on fundamental decisions on public health and safety.

Neither conceptual or computational uncertainty can be reduced to zero. All that can be expected is a reasonable attempt to constrain repository impact over the period of regulatory concern to ~~a domain of realities~~ which satisfies regulatory standards. Most of this burden falls on the DOE, but in developing its licensing review capability the NRC has systematically embarked on a program of research on natural analogues that is described in Appendix D. This program is intended to provide ~~an~~ independent check on how well the DOE program is dealing with those processes and events whose effects may cause repository performance to diverge from predictions over extremes in time, temperature and physical dimension. While analogues are themselves a topic of special interest, they are discussed in this plan in the topical areas where their information can best supplement the regulatory process.

2.3.5 Scheduling Strategy - Timeliness

The overall strategy for the NRC HLW research program schedule is to be responsive to the schedules governed by the HLW regulatory strategy and schedules detailed in the HLWM Program activities. The major targets for the scheduling strategy are driven by the need for HLWM to provide ~~LA~~ guidance to DOE in ~~1998~~. ~~This guidance comes largely from the~~ LARP, which consists of ~~CDMs for~~ the KTUs developed based, on part, from results of the NRC HLW research program. Because of resource constraints, timeliness ~~needs~~ can be an important factor in prioritization. It should also be recognized that some of the HLW research is expected to be of a confirmatory nature, such as in the case of the IPA model assessment.

2.3.6 Assurance of Quality - Peer Review Strategy

The NRC HLW research program will be reviewed at various levels to assure quality, using a number of different mechanisms. This draft plan will be reviewed by the ACNW and the NSRRC. In addition a request for peer review will be published in the Federal Register Notice (FRN)) and copies of the "draft for comment" report will be made available through broad distribution, as well as by special request from the FRN. Depending upon the range and scope of the review comments, RES may conduct a public meeting prior to publication of the final plan draft. This meeting could be structured topically, by program element, by discipline or down to the individual project, if necessary. This process could be followed for future updates of the plan, depending upon the nature and extent of the changes to the research program.

The on-going research program ~~and results~~ will also be peer-reviewed at the program element level (e.g. hydrology, geochemistry, geology) periodically by NRC through use of the NRC research review groups comprised of RES and NMSS staff and independent, invited consultants who provide review comment to the NRC staff on an individual basis (without consensus). Panels of independent experts could also be retained by NRC as part of a periodic peer-review process, where experts are obtained through the use of a broad Agency Announcement. This approach has significant resource impacts which must be considered.

The major mechanisms for peer-review of individual research projects or selected, high impact research results will be ~~implemented~~ by the contractor (1) who can conduct peer-reviews using independent expert panels (such as have been conducted by the CNWRA for two research projects); (2) through traditional publication in the open-literature, including peer-reviewed scientific journals; and (3) through presentations at technical scientific meetings and workshops on the domestic and international level.

2.3.7 Coordination with DOE Program

The purpose of NRC HLW research in the context of NRC's HLW licensing role was described in Section 1.3. It is not the staff's strategy or intent to duplicate or "get ahead" of the DOE program. In each of the research program element areas described in Appendix A, a brief discussion of the on-going DOE effort is provided and placed in perspective to the NRC research efforts leading to a rationale and justification for the NRC work. Again, it should be noted that the need for the NRC work is driven by those key technical uncertainties that are expected to have the greatest impact (risk) ~~for~~ on compliance determination.

Coordination with the DOE program is accomplished by several mechanisms, and within the guidelines and restrictions imposed by NWPA and NWPAA. The principal objective of the coordination mechanisms is to have access to results and information developed under the DOE program for various applications to NRC research and licensing, in addition to assuring that unnecessary duplication and/or overlap does not occur in the NRC research or TA programs. The ~~formal~~ mechanisms of coordination and information exchange include NRC-DOE ~~Technical Exchange~~ and Appendix 7 of the ~~NRC-DOE Memorandum of Understanding for site visits and data set acquisition under the 1984 Morgan-Davis Agreement~~. The status of the DOE program is also described in the semi-annual DOE site characterization progress reports mandated in the 1987 NWPAA.

Useful interactions involving information exchange and program status occur at meetings of the NWTRB and the ACNW at NRC sponsored workshops, and at international cooperative activities such as INTRAVAL. Of course, the traditional mechanisms for obtaining information about the DOE program include the open literature and professional meetings and conferences, all of which include opportunities for interaction ~~of~~ by NRC staff and contractor researchers.

2.3.8 International Cooperation

International cooperation greatly facilitates the intercomparison and testing of models and supporting data bases that will be used to assess the performance of a high-level waste repository. The NRC staff has a need to track and keep

"Procedural Agreement Between the U.S. Nuclear Regulatory Commission and The U.S. Department of Energy Identifying Guiding Principles for Interface During Site Investigation and Site Characterization."

abreast of the research activities of other nations and of international advisory organizations. Participation in international experimental and analytical research activities provides ~~the best~~ an opportunity for the staff to obtain informal comment on NRC staff positions and issue resolution strategies. Moreover, participation in international cooperative research provides the staff with a robust, long-term opportunity for continuing scientific exchange and cooperative research on a wide range of high-level nuclear waste management issues. There are unique natural analogue sites around the world that are most effectively investigated by multinational projects. There are unique laboratory and underground capabilities that are made available to the NRC through multinational investigations that also bring together expertise, pool resources, and reduce costs to individual countries. Strong peer review can be given to models and data by international assessment and intercomparison.

The NRC staff incorporates international research results into the licensing program and participates in international projects of major potential benefit to the NRC. The NRC cooperates in research through: (1) international agreements with Australia, France, Japan, Sweden, Switzerland, and the United Kingdom; (2) one project of the Organization for Economic Cooperation and Development (OECD) (International Transport Validation Project (INTRAVAL)); (3) two initiatives sponsored by the Commission of the European Communities (CEC), the Natural Analogue Working Group and the Oklo project; and (4) the multi-national DECOVALEX project (International co-operative project for the DEvelopment of COupled models and their VALidation against EXperiments in nuclear waste isolation) which is being managed by the Swedish Nuclear Power Inspectorate (SKI). In addition, a project to study seismic transfer functions and seismic effects on groundwater and underground openings is being jointly funded by NRC and the French Atomic Energy Commission (CEA) at Garner Valley California; NRC and SKI staff are working jointly to develop a strategy for testing and assessment of performance assessment models; and the CNWRA Pena Blanca and Akrotiri analogue projects are being carried out with the cooperation of Mexican and Greek authorities, respectively. More detail on the individual projects is presented in Appendix A.

NRC's international cooperation in high-level nuclear waste management has involved many nations both on a bilateral and a multilateral basis. Moreover, the NRC is a member of the Nuclear Energy Agency (NEA) of the Organization of Economic Cooperation and Development (OECD).

Enc 3

GEOLOGY REVIEW

EXCERPTS FROM NOTE TO REX WESCOTT FROM JOHN TRAPP

The following provides the comments of the HLWM Geology/Geophysics section on the geology portion of the draft Research Plan. These comments are intended to respond to the points raised in the Federline to Holonich/Ballard Note requesting review.

General - positive:

a) The completion dates of the studies listed in the plan in Appendix A.6 appears to be soon enough in the future that the material will be available in sufficient time to help resolve NMSS technical concerns.

b) The information contained appears to represent a concerted effort to address identified NMSS user needs.

c) Research has addressed known KTUs.

General - negative:

a) There are concerns related to the technical accuracy of some of the material presented

b) There are concerns with the tone of some of the statements made within these sections

c) There are concerns because many of the geologic KTUs have become subordinate to (or be subsumed within) the performance assessment KTUs. The wrong impression is being presented on our knowledge and ability to deal with geologic uncertainties.

d) The dates listed on page A-6 do not appear to correlated with the dates listed on page A-77 or in Table A.6.

e) The program shows no activity occurring after FY 96.

The concerns related to Items a and b, above, were discussed with L. Kovach and G. Birchard on March 9, 1993. Based on format concerns raised by RES the sections in which the concerns were noted will be substantially revised. The RES personnel noted the concerns raised and will incorporate the concerns in the revision.

The concerns related to Item d were discussed with the RES staff and prior to issuance of the plan these tables will be checked and revised as necessary to assure consistency.

The concerns related to Item e were also discussed with the RES staff and as the lack of input past FY 96 reflects an incomplete planning process the final document will contain some indication that work is planned past FY 96, but details are as yet unknown.

Specific comments.

1. Tone. This is implying a thought process by DOE which can not be documented.

2. Technical. The DOE has acknowledged 32 faults with Quaternary movement, not 5. The five faults they many times talk about include the "larger faults" such as the Bare Mountain Fault and the Rock Valley Fault. See SCP tables 1-7 and 1-8.

3. Tone and Technical. There is still much ongoing debate on these features. See Acrhembauh (sp), for example. In addition, "Extensive" data is giving USGS and DOE more credit them is warranted.

4. Tone, etc. As above, the problem has not been ultimately resolved, and the extensive, carefully measured and analyzed data is putting a fairly strong value judgement which is hard to support.

5. Tone. Throughout here it seems to imply that we will be gathering the data to determine if the site should be licensed. DOE will be gathering the data. We need research to help us figure out how to handle a bunch of the problems with the data.

6. Technical. This is either way too little, or way too much information. It does not appear to be necessary.

7. Technical. Awkward, misleading sentence. There was a lot more than the Timber Mountain that happened 16-10 million years ago.

8. Technical. According to such places as page 1-89 and 1-110 of the SCP, extensional faulting proceeded, accompanied, and followed the evolution of the calderas,and extensional faulting was contemporaneous with volcanism. In addition, there really is not a single DOE model, and there are more outside models then the Wernicke, et al., models.

9. Technical. Suggest that faulting should be added to your list.

10. Technical and tone. This paragraph, Implies a heavy reliance by research on a tectonic model in which the east-west seismic belt becomes the major, or at least one of the major, elements. Other models can be proposed, and should be used research to evaluate the tectonic framework of the region.

11. Technical. The statement that recent volcanism correlates with areas of elevated seismicity and that volcanism near Yucca Mountain appears to correlate with faulting implies technical knowledge which NMSS does not have. Where has these exact statements been document?

12. Same as 10.

13. Technical. Carr, 1992, sees no evidence for the detachment faults based on examination of the core at Yucca Mountain. This contrasting information should also be presented.

14. Technical. Reference to Trapp should be changed to Snyder and Carr for Gravity data and Evans and Smith for tomography.

15. Technical. While complexity may be a large factor, the total lack of site characterization data - especially geophysics- plays a major role in our lack of understanding of the problem.

16. Technical. While NMSS would presently favor the polycyclic interpretation, Champion and Turrin have published information which disagrees with this model.

17. See comment 5.

18. See comment 13.

19. Technical. This section is awkward and hard to follow. There are better examples of concerns with segmentation then those raised.

20. Technical. Do you mean surface rupture?

21. Technical and tone. The justification provided appears to suggest that this is an activity that should be undertaken by DOE.

22. See comment 5.

23. See comment 5 and 21.

24. Technical. This appears to be missing the main point of the RES Need Statement. We have reports which indicate that fault displacement may not show up in the trenches, even when faulting if known to occur. Therefore, how confident are we if a trench shows no faulting?

25. Tone. We are not sure what the last part of this paragraph is saying. In addition, see comment 21.

26. Technical. We would like a better understanding of what is being proposed in this activity. It sounds slightly different from the mantle modeling previously discussed.

A.6 Geology, *Linda A. Kovach, George F. Birchard*

A.6.1 Introduction

A.6.1.a Background

Geologic stability was the underlying concern of the NRC staff when it wrote many of the siting criteria in 10 CFR Part 60, the NRC's regulations controlling HLW disposal. In recommending the Yucca Mountain location as the proposed site for an HLW repository the U.S. Geological Survey and the U.S. Department of Energy staff believed that present day geologic activity was insignificant at Yucca Mountain. It was believed, particularly in the case of volcanism [R235], that intense geologic activity occurred ten to fifteen million years ago but had declined to minimal levels in the Quaternary. The DOE has stated [R156] that although there are five known active faults within the immediate vicinity of Yucca Mountain, that their rate of movement is too low, about 0.01 mm per annum, to pose a significant threat to repository stability. Larger faults in the region within about 50 km of Yucca Mountain, such as the Bare Mountain fault, the Rock Valley fault and the Northern Death Valley fault, are believed by the DOE to pose little risk because of their distance from Yucca Mountain.

Several years ago concerns about the potential of seismic and tectonic forces to cause ground water to rise to the proposed repository level and above were raised by a DOE staff member [R241]. The DOE supported investigations to disprove that certain features, such as calcite and silica vein deposits at "Trench 14" along the Bow Ridge fault, were caused by seismic pumping. Extensive DOE and US Geological Survey data are consistent with a pedogenic origin for the Trench 14 deposits, not with seismic pumping [R240].

This case is important to the NRC because it foreshadows events that could occur as the licensing process progresses. It is germane to the use of expert opinion-based probabilistic seismic hazard assessment methods [R237] in assessing the geologic stability of Yucca Mountain. The Center for Nuclear Waste Regulatory Analyses (CNWRA) concluded, in its review of the literature on probabilistic fault displacement and seismic hazard analysis [R238] that: "Reliance on expert opinion in lieu of data does not provide a high level of confidence in results." In the case of the Trench 14 vein deposits there were two sets of experts with opposing views. Extensive, carefully measured and analyzed data ultimately resolved the impasse. If licensing is to proceed with confidence, the NRC must ensure that the DOE characterize the site sufficiently well to understand the tectonic, seismic and volcanic features and processes that will affect the long-term geologic stability of the site. Moreover, the NRC needs its own research to provide a defensible technical basis for its licensing decisions in critical areas concerning geologic stability. These needs have been identified based upon systematic regulatory analysis involving the coordinated efforts of the CNWRA, NMSS and Research staff members. Focused NRC research will establish NRC's licensing independence from the DOE and will increase the objectivity and credibility of the NRC and CNWRA staff, in addition to providing a technical basis for developing guidance to DOE site characterization to obtain sufficient data

necessary for effective, timely closure of site geological stability issues.

Present day geologic processes at Yucca Mountain are influenced by the geologic history of the southern Great Basin. The geologic history of the southern Great Basin, in which Yucca Mountain is located, has been strongly affected by its proximity to the boundary between the Pacific and North American plates since the Mississippian period [R234]. From the Mississippian to the Jurassic, subduction was accompanied by terrain accretion and thrusting. From the Cretaceous to the Eocene, an eastward dipping subduction zone was associated with compressive tectonics in an Andean-type continental margin. Extension began in the Great Basin in the Oligocene in the back arc setting as subduction continued. There is little evidence, however, that the region around Yucca Mountain was initially affected. However, the long period of subduction thickened the crust, establishing conditions favorable for future extension.

Major extensional processes began affecting the southern Great Basin around Yucca Mountain following the formation of the San Andreas fault. The voluminous silicic volcanism of the Southern Nevada Volcanic field formed Yucca Mountain and the Timber Mountain caldera complex from 16 to 10 million years ago [R156]. There are conflicting interpretations concerning the amount of extension that occurred in the region south of the Southern Nevada Volcanic field. According to Wernicke, Axen and Snow [R243], major extension occurred concurrently to the south of the Southern Nevada Volcanic field in a region extending along the Las Vegas shear zone. Wernicke, Snow and Walker [R244] proposed that Paleozoic basement blocks pulled apart and that Yucca Mountain and the alluvial basins separating major mountain blocks such as the Spring and Funeral mountains are underlain by rocks that rose upward from mid-crustal levels. Wernicke Snow and Walker's model predicts that only incomplete Paleozoic fragments will be found to underlie Yucca Mt, the Amargosa Desert, and the adjoining basins. The DOE model proposed in the site characterization plan [R156] is that minimal extension occurred while massive volcanism took place in the Timber Mountain caldera complex (forming Yucca Mountain) preserving complete Paleozoic sections underneath the volcanic and alluvial cover of Yucca Mountain, the Amargosa desert and the adjoining basins. The differences between these models could affect assessments of faulting, seismicity, volcanism and regional ground water hydrology. Both models agree that about ten million years ago this period of major silicic volcanism and extension began to wane.

Seismic and volcanic activity are the two largest hazards of geologic activity and instability. Large-scale tectonic processes are generally associated with earthquakes and volcanoes. Tectonic boundaries are typically identified by lines or arcs of seismic or volcanic activity. Monitoring for the last 90 years shows an east-west arc of seismicity that can be traced from northern Owens Valley in California, through southern Nevada and the Nevada Test Site connecting with a north-south arc of seismicity along the Wasatch Front in Utah (Figure A.1). The northern Owens Valley is the northern end of a nearly linear arc of high seismic activity that runs through the Mojave Desert and connects with the San Andreas fault along an active zone recently named the Mojave shear zone (Savage, Lisowski and Prescott, 1990). The southern end of this zone was recently ruptured by the Landers earthquake. The U.S.

Geological Survey is conducting geodetic surveys that show that the deformation rates along the Mojave shear zone of approximately 8 mm/yr are much higher than deformation rates along the Wasatch Front. Records of historic seismicity show that the east-west zone that runs through the Test Site appears to be somewhat less active than the Wasatch Front. Moreover, recent volcanism correlates with the areas of elevated seismic activity. Volcanism near Yucca Mountain appears to correlate with faulting.

Very long baseline interferometry (VLBI) and other geodetic data determine that about 20% (9 mm/annum) of the relative motion of the Pacific and North American plates [R239] is occurring in the northern Basin and Range. Further analysis of the seismic data shows very little activity east of the Mojave shear zone in California and south of the east-west arc from California to Utah, excepting reservoir induced seismicity associated with Lake Mead. The seismicity pattern may be reasonably interpreted to show that the eastern Mojave desert and southern Basin and Range in southernmost Nevada and through most of Arizona is not active. Nevada Test Site (NTS) seismicity has been attributed by the DOE to the stress relief resulting from nuclear weapons testing [R156]. However, careful removal of events associated with nuclear testing and mine blasting [R242] removes only one active point in the long east-west seismic arc and leaves it intact. Moreover there is a topographic step from low southern elevations to high northern elevations that correlates with the elevated seismicity. The east-west zone appears to be the boundary between the inactive southern Basin and Range and the actively extending northern Basin and Range. Geodetic data are needed to determine the significance of the east-west zone and major faults in the region to the geologic stability of Yucca Mountain. It is difficult to establish a correlation between the surface geologic structure and earthquake focal mechanisms around Yucca Mountain. Earthquake first motion studies indicate predominantly right-lateral strike-slip focal mechanisms. The minimum principal stress axis is oriented in a northwesterly direction and the maximum stress is vertical in the Yucca Mountain region [R245]. This stress field favors right-lateral strike-slip motion on northwest/southeast oriented faults, normal motion on N-NE oriented faults and left-lateral motion on E-NE oriented faults. In the region around Yucca Mountain, faults of all these orientations are found. Additionally, technical assistance sponsored detailed analyses of structural geologic data by the CNWRA support the hypothesis that a low angle detachment fault underlies Yucca Mountain (Young, Stirewalt and Morris, 1992). Moreover, geophysical data indicate a vertically oriented feature of unknown origin directly underneath Yucca Mountain (Trapp, pers. comm). Given the complexity of the structure of faulting at and near Yucca Mountain, it is difficult to understand the relationship between faulting and seismicity there. There appears to be a relationship between volcanism and faulting in Crater Flat but it to is difficult to understand because of the complexities in faulting.

The most critical geologic issues at Yucca Mountain concern geologic processes and events that could disrupt repository performance. Volcanism and associated hydrothermal activity in a worst case scenario would affect the repository directly by magma intrusion or indirectly by affecting the flow of groundwater at the site. Recent research [R213] on the basaltic cinder cones in Crater Flat and at Lathrop Wells, Nevada, indicate that several of the

volcanic centers exhibit polycyclic volcanism rather than monogenetic (single eruptive events) behavior, as previously thought. Polycyclic volcanic centers have been characterized as small volume volcanic centers that (1) exhibit intermittent, multiple eruptions from closely spaced volcanic vents, (2) exhibit eruptive behavior over long time spans (1,000 to 100,000 years), (3) exceed 100,000 years' duration of activity of a center, (4) increase in volatile content of magma with time (pyroclastic eruptions are possible), and (5) decrease in eruptive volumes with time. The most recent K-Ar dates for the Lathrop Wells cone (10,000 years) and geomorphologic studies of the cone shape and soils suggest an age significantly younger than 100,000 years [R213]. This information, coupled with the polycyclic behavior of the volcanic centers, provides strong evidence that the issue of future volcanism in the vicinity of Yucca Mountain should be investigated.

A.6.2.b Research Interfaces

Research in the engineered systems area of the NRC HLW research program is investigating the effects of earthquakes on underground structures. Hydrology and climatology research in the program's hydrology area is investigating the changes in rainfall, groundwater recharge, and water levels that could affect aspects of the geologic system such as the likelihood of phreatomagmatic events. Research in the geochemistry area is investigating zeolites that may provide indications of specific geologic processes.

A.6.2 Systematic Regulatory Basis

A.6.2.a Key Technical Uncertainties

Potentially adverse conditions: Structural deformation (Review Plan 3.2.1.5)

- **Poor resolution of exploration /techniques to detect and evaluate structural features (Type 4)**
- **Evaluation of fault mechanisms in alluvium (Type 5)**
- **Development and use of conceptual tectonic models as related to structural deformation (Type 5)**

Potentially adverse conditions: Correlation of earthquakes with tectonic processes (Review Plan 3.2.1.7--DRAFT)

- **Ability to predict the likelihood of earthquake recurrence (Type 4)**
- **Development and use of conceptual models related to seismic activity (Type 5)**

Potentially adverse conditions: Increasing earthquake frequency/magnitude (Review Plan 3.2.1.8--DRAFT)

- **Ability to predict the likelihood of earthquake occurrence (Type 4)**
- **Development of tectonic models used to define seismicity (Type 4)**
- **Attenuation of seismic ground motion in the Basin and Range province (Type 4)**
- **Elicitation and analysis of expert opinions used in lieu of seismic data (Type 4)**
- **Age dating of paleo fault offsets (Type 4)**

Potentially adverse conditions: Evidence of igneous activity (Review Plan 3.2.1.9--DRAFT)

- Poor resolution of exploration to detect and evaluate igneous features (Type 4)
- Inability to sample igneous features (Type 5)
- Development and use of conceptual tectonic models as related to igneous activity (Type 5)

A.6.2.b User Needs Addressed

601 Evaluation of mechanisms and processes that control the location of igneous features
602 Evaluation of past temporal and spatial patterns of igneous activity
603 Evaluation of effects of igneous activity on groundwater flow
604 Evaluation of theories of multiple volcanic eruptions
605 Evaluation of age-determination techniques in volcanic terrain
606 Evaluation of the appropriateness, precision, and accuracy of probabilistic seismic hazard analysis for long term predictions.
607 Evaluation of distributive faulting characteristics of the Basin and Range
608 Evaluation of fault segmentation characteristics in the Basin and Range
609 Evaluation of fault displacement and basaltic volcanism as contemporary events
610 Evaluation of fault mechanism in alluvium
611 Evaluation of Quaternary strain rate estimates
612 Modeling of fault activity using computer-aided techniques
703 Validation of mathematical models

reword

A.6.2.c Approach to Addressing Key Technical Uncertainties and User Needs

The geologic concerns about the Yucca Mountain site are highly visible and controversial. There is concern that they could be fatal flaws of the site. Therefore, the NRC will initiate research to develop independent support for licensing decisions on the probability of disruptive geologic events and processes and their possible effects on repository performance. NRC research will study regional data and other sites at which the same geologic processes and events occur. The tectonics of the region will be studied and closely coupled with the research on volcanism in an attempt to understand the rates and underlying mechanism of volcanism at Yucca Mountain.

It is anticipated that the geology research will provide information on the probabilities of disruptive processes and events for performance assessment. Interaction between research geologists and performance assessment will be needed to develop parameter values and scenarios for modeling disruptive events and processes. It is expected that the research results will provide alternative scenarios and parameter values that will provide a basis for assessing the uncertainties in DOE-provided scenarios and parameter values for

12

NO! KEEP ... PROCESS ... ETC ...

disruptive geologic events and processes.

Risk assessment of volcanic hazards at Yucca Mountain is based on a probabilistic approach. However, a probabilistic approach without some knowledge of the mechanisms and tectonic processes involved in volcanism will not give an accurate assessment of the potential for future volcanism [R214]. Research on the probability and nature of volcanism in the Basin and Range, in particular on the significance of existing cones in predicting future volcanism, is needed. The appropriate methods for determining the probability of future volcanic activity must be addressed. The temporal and spatial scales of volcanic activity in the Basin and Range which must be considered to gain a better understand processes of magma genesis and ascent. The relationship between mantle dynamics, regional extensional tectonics, and surface volcanic activity needs to be addressed. These issues will be addressed through a program of field studies, analytical methods, and theoretical modelling at the Center through a series of projects. Under the current tectonic regime, the factors controlling emplacement, eruptive style of volcanic activity and resultant hydrothermal processes will be assessed through a field study of analogous volcanic fields and/or active cinder cones.

Tectonic activity in a worst case scenario might allow the water table, which is much higher to the north of Yucca Mountain to saturate the repository and greatly increase groundwater flow rates. The following are issues will be considered in the tectonic research at the Center: appropriate methods for estimating earthquake probabilities and their uncertainties, the relationship between zones of higher seismic activity such as the Walker Lane zone and Yucca Mountain seismicity, the effects earthquakes and tectonic cycles have on water levels, the recurrence interval of major earthquakes for the Death Valley fault system, the affect of earthquakes on underground structures, the variation of ground motion with depth, the variation of Basin and Range faults with depth, the nature of normal faults that bound Yucca Mountain at depth (flattening with depth), the proximity of near-horizontal faults that may pass under the Yucca Mountain repository, the likelihood that near-horizontal faults could be reactivated.

The Cedar Mountain earthquake and other earthquakes in the southern Great Basin have produced displacements on multiple fault segments. The Landers earthquake ruptured multiple fault segments with significantly differing orientations. Thus, it is difficult to establish relationship between the length of a fault segment and the maximum possible magnitude of an earthquake in this region. A better understanding of the nature of fault segmentation in the Basin and Range is needed. Moreover, a number of a magnitude 6 range earthquakes have occurred in the Basin and Range region without showing any surface expression. Thus, to be able to develop a basis for estimating a probability distribution for earthquake location, magnitude and recurrence interval, it is essential to gain primary information on the rates of movement of various faults and structures in the region. A detailed understanding of both modern rates of strain and Quaternary rates of deformation is essential to understanding the tectonic picture. The DOE is sponsoring geodetic surveying at the NTS that will help to understand deformation rates in the area extending from Yucca Mountain to the north and east. More needs to be known about the extent of deformation in the region to the west between Yucca

Mountain and Owens Valley to understand the stability of Yucca Mountain.

The DOE has undertaken a number of fault trenching studies to attempt to determine the rates of offset along the faults in the immediate vicinity of Yucca Mountain [R156]. However, it should be recognized that trenching studies provide minimum rates of offsets because: (1) they may not intersect all fault segments; (2) later earthquakes may obfuscate the effects of earlier earthquakes; (3) alluvium and near surface materials may deform over a broad volume near the surface and offsets may increase with depth. The Landers earthquake produced a number of scarps that were not coincident with older fault rupture exposures. Clearly, the nature of faulting in alluvium needs further research, especially applied towards interpreting data derived from trenching studies. Moreover, techniques for dating fault offsets around Yucca Mountain may be highly speculative because closed system conditions do not appear to have existed. Closed-system conditions are generally needed for precise geochronological studies. Thus it is difficult to determine the amounts of offset on a fault and the timing of events that produced the offset. Geochronological data gathered at Yucca Mountain involve materials, ages and conditions that are beyond the present state of the art for reliable paleoseismic dating.

The NRC needs to assess geophysical and geological methods that provide an independent check of fault trenching data developed by the DOE. The methods investigated by the NRC should be reasonably conservative. Specifically, NRC-supported investigations should provide realistic maximum rates of deformation which would confirm or negate DOE's minimum rates.

There are two general approaches to measuring large-scale strain rates in the Basin and Range province. The first is to measure contemporary strain directly by geodetic methods such as GPS. This approach has been proposed to the NRC by Wernicke and Davis and is an integral component of NRC's research on tectonics. The second approach is to determine long-term rates of offset by large-scale reconstruction of geologic features affected by deformation or offset and to integrate the surface geology, geologic structure and dynamics of the crust and upper mantle in a strain-compatible model. This type of model would provide a conceptual low-resolution three-dimensional motion picture of the tectonics of the region. Allmendinger et al. [R234] and Wernicke, Snow and Walker [R244] have shown that the "tectonic heredity" and structural history of a region affects its present day behavior. The structure of Paleozoic and early Mesozoic thrust faulting may be critically important to reconstructing Quaternary and Tertiary extensional terrains. Likewise, volcanoes may be used as probes of lower crustal and upper mantle conditions. They provide unique petrological, geochemical and geophysical data for understanding the physical processes that are controlling lower crustal and upper mantle dynamics. Thus a geology research program needs to integrate tectonic, volcanological, geophysical, structural geological, and geochemical data to develop a systematic basis for evaluating the geologic stability of the region around Yucca Mountain.

A.6.3 Research Activities and Schedules

A.6.3.a Continuing and Planned Research

Research is beginning on the tectonics of the Basin and Range Province and its relationship to structural deformation and seismicity in the Yucca Mountain region. A synthesis of data and models concerning tectonic processes in the central Basin and Range region, in which Yucca Mountain is located, will be developed. This synthesis will be the foundation for the development of scenarios for geologic events and processes affecting Yucca Mountain. The probabilities and uncertainties of seismic and tectonic events and processes and the probabilities of associated effects, such as water table elevation changes, that might effect the HLW repository will be assessed. The association of earthquakes with topographic and gravity anomalies in the region will be assessed. The relationship between regional strain and seismicity will be assessed in light of the potential of activating faults in the vicinity of Yucca Mountain.

The Center's research will seek to address the user need statements directly on a broad basis and will identify the nature and extent of additional detailed research required by the NRC and DOE to deal with the user needs successfully. Specific areas possibly requiring detailed investigations following Center literature review and synthesis activities concerning the geology and tectonics user needs may include areas such as the mechanics of faulting in alluvium. The DOE is undertaking a number of fault trenching studies to determine the extent of quaternary offset on faults in and around Yucca Mountain. However, recent studies, reported at the December, 1992 American Geophysical Union meeting, of the Landers earthquake show that the exact previous fault trace was often not followed in alluvium. Thus fault trenching in alluvium could overlook nearby evidence of previous rupture events along a fault by focusing on the most recent fault scarp in alluvium. Moreover, the Landers event showed that alluvium is subject to deformation controlled by geologic structures in certain locations.
Thus, the Center is evaluating the possibility of conducting detailed research in the Mojave desert at sites affected by the Landers and previous earthquakes to develop a better understanding of fault rupture processes in alluvium. This research would benefit the NRC by providing key information for interpreting DOE studies on faulting in the Yucca Mountain area.

Research has started on geodetic studies to address key technical uncertainties concerning developing conceptual tectonic models related to: 1) structural deformation; 2) seismic activity and 3) igneous activity. Regional Global Positioning Satellite interferometry (GPS) measurements will be repeated over a five year period across key geologic structures in the region from Jackass Flats to Owens Valley to help address these three key technical uncertainties. This study is along an east-west orientation and will help resolve uncertainties concerning the extent of deformation that occurs east of Owens Valley. The DOE is supporting repeat laser ranging geodetic studies by the U.S. Geological Survey of the Nevada Test Site which will help resolve models of deformation along a primarily north-south orientation. Conceptual models may be bounded by upper limits on deformation rates determined by geodetic studies for structures with low deformation rates.

Research has also started on studies of fault cements to understand their

origins and their significance with respect to the earthquake rupture cycle. Detailed characterization of the mineralogy, chemistry and isotopics of fault cements from deep boreholes in sedimentary basins will be undertaken. Models of basin deformation will be integrated with hydrogeochemical models to understand the origins and significance of fault cements.

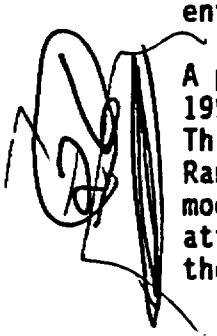
Research on the uncertainties involved in application of geologic dating methods to faulting, volcanism and coupled hydrological processes in the Basin and Range is planned to begin in FY 1994.

A project on volcanism in the Basin and Range Province and its relationship to tectonics started at the beginning of FY 1992. This project will examine different means of estimating probabilities, and the associated uncertainties, of future volcanic activity. The investigation will be based on regional volcanic and tectonic data, and perhaps data from other sites at which the same geologic processes and events occur. Included in the study will be a compilation of existing data on rates of tectonism, eruptive volumes, magma composition, eruptive style, age, and any other relevant parameters for both basaltic, intermediate, and silicic volcanism in the Great Basin during the Cenozoic.

A project to investigate polycyclic volcanism also began in early FY 1992. This project will address the thermal requirements and mechanics of multiple eruptions from a single vent over long time spans. The study will utilize an interdisciplinary approach through (1) a detailed petrologic and chemical examination of the interior of an exposed volcanic neck that is analogous to the basalts found in Crater Flat and (2) an exercise to model the thermal regime of the host rock and transport of the magma within the conduit.

A research project is underway at Florida International University through the NRC Research Grants program which will investigate the structural control on volcanic vent alignment at the San Francisco volcanic field.

A project on volcanic field studies has been initiated in FY 1993. The objectives of this project are 1) to increased knowledge of subsurface volcanic structures and the adequacy of geophysical site characterization techniques to identify subsurface igneous structures, and 2) to determine the likelihood and consequences of small volume basaltic eruptions and near surface magmatic events which could potentially disrupt a HLW repository. This project will include detailed field investigations of several volcanic fields in the Basin and Range, and may also include the study of presently active basaltic volcanoes in an attempt to better understand eruption dynamics and associated hydrothermal activity and its affect on the repository environment.



A project to model volcanic processes and mantle dynamics is planned for FY 1995.
This project will utilized seismic tomography data compiled for the Basin and Range and tomography of the Crater Flat region coupled with forward kinematic modelling of the region and upper mantle. The product of this will be an attempt to view various tectonic and magmatic scenarios 10^5 to 10^7 years in the future.

A.6.3.b Key Accomplishments

Most of the projects referenced above have been initiated within the last fiscal year and as such have no key accomplishments. The Center published "A

Review of Pertinent Literature on Volcano-Magmatic and Tectonic History of the Basin and Range" in 1992, completing a major milestone for the Volcanics of the Basin and Range project.

A.6.3.c Schedules

The following is a list of products for the above metioned geology projects. Each project is listed with the anticipated products and dates.

Volcanism of the Basin and Range

- Literature review. Completed FY93.
- Database and topical report on Compiliation and critical review of volcanic database for the Basin and Range (FY94).
- Topical report on Development of coupled tectono-volcanic model for Basin and Range (FY95).
- Topical report on assessment of predictive models of future volcanism in the vicinity of Yucca Mountain (FY95).

Volcanic Field Studies

- Report on selection of analogous volcanic sites for study of eruption mechanisms and disruptive scenarios (FY93).
- Report on evaluation of geophysical techniques for identification of subsurface igneous features, data and field relations from field investigations (FY95).
- Report on eruption mechanics and volatile content of potentially eruptive phases (FY95).
- Report on hydrothermal effects to host rock and repository associated with basaltic intrusion (FY96).

Polycyclic Volcanism

- Report on mechanisms leading to the polycyclic eruptions (FY94).

Volcanic and Mantle dymanic Modelling

- Report on modelling methodology (FY95).
- Report on the potential for future igneous activity in the vicinity of Yucca Mountain, based on forward modelling approach and tomographic data (FY96).

Tectonics Field Studies and Modelling

- Geodetic data and deformation models to constrain tectonic and structural models (FY93-95).
- Fault cement geochemical data, isotope models and basin deformation models to assess origins of fault cements (FY93).
- Develop CNWRA tectonics research plans (FY93).
- CNWRA field data & models for Yucca Mt. scenarios, tectonic, structural & conceptual models (FY94-96).

Table A.6: HLW Geology Research Schedule

Activity	User Needs	CY93	CY94	CY95	CY96	CY97	CY98	CY99	CY00	CY01
Repository Schedule Surface Testing ESF Operation In-situ Testing		---- ----	---- ----	---- ----	---- ---- --	---- ---- ----	---- ---- ----	---- ---- ----	---- ---- ----	---- ---- ----
Tectonics Literature review	601, 606	--X								
Geophysical Data compilation & critical review	602, 606	--X								
Tectonics field study	606, 703	-	----	--X						
Dating methods for tectonic processes	606	-	---X							
Mathematical models of tectonic processes	606, 703	----	----	----	---X					
Volcanism field study	603, 605, 703	--	----	---X						
Dating methods for volcanic processes	602, 605	--	---X							
Mathematical models of volcanic processes	603, 703		--	----	---X					

Table A.6: HLW Geology Research Schedule										
Activity	User Needs	CY93	CY94	CY95	CY96	CY97	CY98	CY99	CY00	CY01
Repository Schedule Surface Testing ESF Operation In-situ Testing		---- ----	---- ----	---- ----	---- ---- --	---- ---- ----	---- ---- ----	---- ---- ----	---- ---- ----	---- ---- ----
Polycyclic and monocyclic volcanism	604	----	---X							

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ATTACHMENT 2

COMPLIANCE DETERMINATION STRATEGY

3.2.1.7 Potential Adverse Condition: Correlation of Earthquakes with Tectonic Processes

APPLICABLE REGULATORY REQUIREMENTS:
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(c)(13)

TYPES OF REVIEW:
Acceptance Review (Type 1)
Safety Review (Type 3)
Detailed Safety Review Supported by Analyses (Type 4)
Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations (Type 5)

RATIONALE FOR TYPES OF REVIEW:
Acceptance Review (Type 1) Rationale:
This regulatory requirement topic is considered to be license application-related because, as specified in the license application content requirements of 10 CFR 60.21(c) and regulatory guide "Format and Content for the License Application for the High-Level Waste repository (FCRG)", it must be addressed by the U.S. Department of Energy (DOE) in its license application. Therefore, the staff will conduct an Acceptance Review of the license application for this regulatory requirement topic.

Safety Review (Type 3) Rationale:
This regulatory requirement topic is considered to be related to containment and waste isolation. It is a requirement for which compliance is necessary to make a safety determination for construction authorization as defined in 10 CFR 60.31(a) (i.e., regulatory requirements in Subparts E, G, H, and I). Therefore, the staff will conduct a Safety Review of the license application to determine compliance with this regulatory requirement topic.

This regulatory requirement topic, concerning a potentially adverse condition (PAC), focuses on DOE's demonstration, through appropriate investigations, of evidence for (or against) this PAC within the controlled area in order to understand the projected effect of this condition, if present, on the waste isolation capability of the proposed geologic repository. It concerns evidence that, based on correlations of earthquakes with tectonic processes and features, either the frequency of occurrence or magnitude of earthquakes may increase. In addition, such investigations shall extend beyond the controlled area if it is ascertained that this PAC might adversely impact isolation within the controlled area.

The Yucca Mountain site is located in an area that is tectonically active (see DOE, 1988, pp. 1-151 - 1-200). Therefore, there is no question that this PAC exists for the Yucca Mountain site; however, there is ongoing debate about the degree to which this condition is present, or may be present and undetected.

Detailed Safety Review Supported by Analyses (Type 4) Rationale:
Projections concerning the potential for and effects of increasing earthquake activity, during the period of performance, may contain a large degree of uncertainty. This uncertainty could cause a high risk of non-compliance with the overall system performance objective specified in 10 CFR 60.112 and the subsystem performance objective for the engineered barrier system specified in 10 CFR 60.113(a). Therefore, the staff considers that findings made under this requirement may be highly uncertain due to the following Key Technical Uncertainty.

The Key Technical Uncertainty associated with techniques to predict the likelihood of earthquake occurrence for 10,000 years is considered to require a Type 4 review because there is a risk of non-compliance with the performance objectives related to containment and waste isolation. This risk necessitates analyses above and beyond that required for Type 3 reviews to assure that the uncertainty, and the effects on performance, have been reduced to the extent practical.

Key Technical Uncertainty Topic: The inability to predict the likelihood of earthquake occurrence during the next 10,000 years.

Description of uncertainty: Due to the complexity of tectonic processes, the lack of knowledge about how the different tectonic processes behave in the Yucca Mountain area, and the short time frame of collected historical and instrumental earthquake data at Yucca Mountain, it will be difficult to predict the recurrence rate of seismic activity at the site. Existing earthquake data for the site can be used for predictions over the short time frame (i.e., up to 100 years). However, for extrapolations of up to 10,000 years, as required by 10 CFR Part 60, there will be a large band of uncertainty which may be difficult to quantify.

Performance Objectives at Risk: 10 CFR 60.112 and 10 CFR 60.113(a).

Explanation of Nature of Risk: A lack of knowledge about the rate and of earthquake magnitude recurrence may lead to an underestimation of the design earthquake needed for structures, systems, and components important to containment and waste isolation. For example, uncertainties regarding the effects of vibratory ground motion on the stability of a corroded waste package canister, or in changes to the waste isolation characteristics of the repository block could result in non-compliance with the performance objectives of 10 CFR 60.113(a) and 10 CFR 60.112, respectively. Therefore, understanding the processes, features, and characteristics related to earthquake activity, both direct and secondary, has a degree of uncertainty which is hard to quantify.

Description of Resolution Difficulty: Closure of this issue will be difficult because, currently, there are no proven methods for extrapolating relatively short-term earthquake data up to the period of 10,000 years after repository closure. Methods are needed to provide reasonable assurance that the effects of increasing earthquake activity are identified and that predictions regarding these effects will not underestimate the actual effects of earthquakes on repository design and performance. As research in this area has not been done, the resolution difficulty for this Key Technical Uncertainty cannot be determined at this time. It is expected that a significant amount of expert judgment will be used in extrapolating short-term seismic data. However, if no methods for extrapolating relatively short-term data, over the period of regulatory concern, are developed, the staff would consider this Key Technical Uncertainty to require a Type 5 review.

Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations (Type 5) Rationale:
Because the following Key Technical Uncertainty may be difficult to resolve, there may be the highest potential risk of non-compliance with the performance objectives specified below.

Key Technical Uncertainty Topic: Correlation of earthquakes with tectonic features.

Description of Uncertainty: Understanding the relationship between seismic activity (earthquakes) and tectonic features for the Basin and Range Province has been and is still the subject of significant uncertainty. The choice of a conceptual tectonic model can have a significant effect on the interpretation of the seismic hazard assumed to affect the geologic repository. For example, in seismic hazard analysis, where seismic source zones are defined based on a correlation between seismic activity and specific structural features, a lack of correlation will lead to large uncertainty in the analysis of the hazard. The choice of one or more conceptual tectonic models could cause changes in the results of the seismic hazard calculations. Because of this large range in permissible models, and the associated uncertainty, this Key Technical Uncertainty is considered to involve a Type 5 review.

Performance Objectives: 10 CFR 60.112 and 10 CFR 60.113(a).

Explanation of Nature of Risk: By definition, models are a simplification of reality, and both conceptual and mathematical models will be used in the high-level waste program. The conceptual model selected can have a significant effect on the scope of the field investigation program, and on the interpretation of the data obtained. In addition, the regulatory requirement itself relates to more than just the presence of certain features; it also requires an assessment of what may be present and undetected. Without a conceptual model of what is being investigated, it is impossible to comply with either the regulatory requirement for this potentially adverse condition or the regulatory requirement related to overall system performance. Conceptual models can be used to describe the assumed physical and/or chemical processes which have, are, or will be taking place within the system under consideration; mathematical models are used in performance assessment to "predict" the behavior of the system. It is impossible to completely sample and describe any physical system which is as complex as that represented by the tectonic activity in the vicinity of

Yucca Mountain. Because uncertainty will exist in the data and parameters, there will be an inherent uncertainty in the understanding of the physical system being represented by the model, and a consequent inherent uncertainty in the correctness or validity of any conceptual model used. This uncertainty will be propagated through the performance assessments, along with the mathematical model uncertainties, introducing an unknown amount of uncertainty in any final results from performance assessment analyses.

Description of Resolution Difficulties: The Key Technical Uncertainty related to correlating earthquakes with tectonic features is considered to require a Type 5 review because very little has been done to reduce the risk of non-compliance with the performance objectives related to containment and waste isolation at this time. According to Davis *et al.* (1990), there is currently no methodology designed to quantify the uncertainty in conceptual models. Also, selection of the model(s) to be used, to correlate seismic activity and tectonic features, will be based, at least in part, on subjective judgement of experts and can, at best, be formalized and documented only to the extent that the assumptions used are clear, reasonable, and traceable.

Summary

The reasons for a Type 5 review can be summarized as follows:

(1) Quantitative knowledge about tectonic processes, including the ability to predict the occurrence of earthquakes for the next 10,000 years or the ability to correlate earthquakes with known tectonic structures, in the Yucca Mountain area is, and will most likely remain, uncertain;

(2) Alternative conceptual models of tectonic processes will remain at the time of licensing;

(3) The alternative models for addressing both the probability of tectonic activity and potential effects from this activity may span several orders of magnitude;

(4) There is no proven method for extrapolating relatively short-term seismic data and experience to the long performance periods (i.e., 10,000 years) required for a geologic repository; and

(5) The effects of tectonic activity on the ability to demonstrate compliance with the overall system and subsystem performance objective will be highly contentious during licensing.

REVIEW STRATEGY:

Acceptance Review:

In conducting the Acceptance Review of the potentially adverse condition (PAC), concerning either an increase in the frequency of occurrence or magnitude of earthquakes (based on correlations of earthquakes with tectonic processes and features), the reviewer should determine if the information presented in the license application and its references for determining compliance with the regulatory requirements applicable to this PAC are complete in technical breadth and depth as identified in the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG). The reviewer should determine that all appropriate information necessary for the staff to review this PAC is presented such that the assessments required by the regulatory requirements associated with total system and subsystem performance objectives can be performed.

The information presented in the license application should be presented in such a manner that the assumptions, data and logic leading to a demonstration of compliance with the requirements are clear and do not require the reviewer to conduct extensive analyses or literature searches. The reviewer should also determine that controversial information and appropriate alternative interpretations and models have been adequately described and considered.

Finally, the reviewer shall determine if the U.S. Department of Energy (DOE) has either resolved all the NRC staff objections that apply to this regulatory requirement topic or provided all the information requested in Section 1.6.2 of the FCRG for unresolved objections. The reviewer will evaluate the effect of any unresolved objections, both individually and in combination with others, on: (1) the ability of the reviewer to conduct a meaningful and timely review; and (2) the ability of the Commission to make a decision regarding construction authorization within the three-year statutory period.

Safety Review (Type 3):

This regulatory requirement topic is limited to the consideration of increases in either the frequency of occurrence or magnitude of earthquakes. It is not concerned with changes to hydrologic conditions caused by seismic or tectonic activity. These topics will be covered under Sections 3.2.2.7 through 3.2.2.9 of the license application and its attendant review plans.

The specific aspects of the license application on which the reviewer will focus are described below, and the *Acceptance Criteria* are identified in Section 3.0 of this review plan. In conducting the Safety Review, the reviewer will, at a minimum, determine the adequacy of the data and analyses presented in the license application to support DOE's demonstrations regarding 10 CFR 60.122(c)(13). Specifically, DOE will need to: (1) provide information to determine whether and to what degree evidence of increasing frequency of occurrence or magnitude of earthquakes is present; (2) provide information to determine to what degree evidence of this PAC is present, but undetected; (3) assure the sufficiency of the lateral and vertical extent of the data collection; and (4) evaluate the information presented in support of Items (1) and (2), with assumptions and analysis methods that adequately describe the presence (or absence) of increasing frequency of occurrence or magnitude of earthquakes and

ranges of relevant parameters. Examples of the specific review activities that will be required of the staff include confirmation that DOE has fully considered the historically reported and instrumentally recorded earthquakes, site and regional tectonic models, and paleoseismic events that are appropriate for the aforementioned analysis.

DOE will also need to provide an explanation of the measures used to support the tectonic models used to assess the presence (or absence) of evidence of increasing frequency of occurrence or magnitude of earthquakes. Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests that are representative of field conditions, monitoring data, and natural analog studies.

In conducting the aforementioned evaluations, the reviewer should determine that DOE uses: (1) analyses that are sensitive to evidence of increasing frequency of occurrence or magnitude of earthquakes; and (2) assumptions which are not likely to underestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations for evidence of increasing frequency of occurrence or magnitude of earthquakes, both within the controlled area and outside the controlled area, as necessary.

In order to conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data such as the results of research activities being conducted by the NRC's Office of Nuclear Regulatory Research, in addition to that provided by DOE in its license application. The reviewer should focus on additional data which can refine knowledge of increasing frequency of occurrence or magnitude of earthquakes, and should perform, as necessary, additional analyses to confirm the resolution capabilities of the methodologies. It is incumbent upon the reviewer to have acquired a body of knowledge regarding these and other critical considerations in anticipation of conducting the review to assure that DOE's seismic program is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

Finally, the following DOE site characterization program study plans are expected to provide data and analyses needed to help in the review described above to address the presence (or absence) of this PAC:

Study Plan No.	*Title*
8.3.1.17.3.1	Relevant Earthquake Sources
8.3.1.17.4.1	Historical and Current Seismicity at Yucca Mountain

Additional study plans related to this PAC, when available, will also be reviewed.

Detailed Safety Review Supported by Analysis:
A Detailed Safety Review supported by analysis will be needed for evaluation of the Key Technical Uncertainty regarding the inability to predict the likelihood of earthquake occurrence during the next 10,000 years. This will ensure that DOE has adequately demonstrated Items (1)-(4), listed in the previous section (see Section 2.2.1 ("Safety Review"), paragraph 2).

Examples of specific review activities that will be required include the review of DOE's seismic analyses to ensure that they have included: (1) all the regional geologic structures and tectonic activity which are significant in predicting the likelihood of earthquake occurrence; (2) a coherent and well documented discussion (of both regional and site tectonics) that was used as the basis for determining earthquake occurrence; (3) an examination of the data and the approach used to predict earthquake occurrence; and (4) a discussion and rationale describing the preferred approach.

Detailed Safety Review Supported by Independent Tests, Analyses, or Investigations: A Detailed Safety Review, independent modeling and the use of the results of staff investigations will be needed for the Key Technical Uncertainties concerning the correlation of earthquakes with tectonic features. This will ensure that DOE has adequately demonstrated Items (1)-(4) listed in the section on "Safety Review" (see Section 2.2.1, paragraph 2).

For the Key Technical Uncertainty concerning the correlation of earthquakes with tectonic features, the staff detailed review will be supported by conceptual and numeric models developed by the staff to determine if the models being used by DOE provide an adequate explanation of the phenomenon of earthquake activity. In conducting this review, the staff must evaluate the different conceptual models to determine if they are consistent with the models being proposed for other related processes. Through various modeling exercises, the staff will develop various tectonic models and attempt to define the correlation between earthquake data and tectonic structures presented by the model.

Examples of specific review activities that will be required include: (1) comparing both the DOE models and models developed by the staff to determine if these models provide an adequate explanation of how earthquakes are generated, and whether historical or predicted earthquakes can be correlated with the tectonic features described in these models; (2) examining the consistency of DOE's models with field observations made during site characterization; and (3) reviewing the assumptions proposed for constructing these models and their rationales, and compare the results presented by DOE, in its license application, to the results of the NRC's independent confirmatory analysis. In conducting this review, the staff must evaluate the consistency and accuracy of the tectonic models developed. The staff investigations that may also include collecting field data and constructing 3-D models.

When reviewing and creating models, it should be recognized that, in addition to field data, subjective judgement will also be required. It is important that the various assumptions necessary for the various models be carefully documented and thoroughly reviewed. Bounding assessments, field data, and the results of the various research activities should be included to narrow and distinguish between the various models proposed. It is anticipated that several conceptual models may be reasonable at the time of licensing. In reviewing these models, the staff must assure that they reflect the degree of resolution of the experimental and investigative methods, including what could be present but may still be undetected due to the limitations of the various methods applied. The staff must also assure that the models used incorporate all appropriate field data and assumptions.

Contributing Analysts:

NRC Staff: A. K. Ibrahim

CNWRA Staff: R. Hofmann

Date of Analysis: December 9, 1992

RATIONALE FOR REVIEW STRATEGY (OPTIONAL):

Not applicable.

APPLICABLE REGULATORY REQUIREMENTS FOR REVIEW TYPES:

Type 1:
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)

Type 3:
10 CFR 60.122(c)(13)

Type 4:
10 CFR 60.122(c)(13)

Type 5:
10 CFR 60.122(c)(13)

REFERENCES:

Davis, P.A., E.J. Bonano, K.K. Wahi, and L.L. Price, "Uncertainties Associated with Performance Assessment of High-Level Radioactive Waste Repositories," Nuclear Regulatory Commission, NUREG/CR-5211, November 1990.

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

U.S. Department of Energy, "Chapter 1, Geology," in "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area," Office of Civilian Radioactive Waste Management, DOE/RW-0199, Vol. I, Part A, December 1988.

U.S. Department of Energy, "Study Plan for 'Relevant Earthquake Sources'," Office of Civilian Radioactive Waste Management, Study Plan No. 8.3.1.17.3.1, July 1990. [Prepared by the U.S. Geological Survey.]

U.S. Department of Energy, "Study Plan for 'Historical and Current Seismicity at Yucca Mountain'," Office of Civilian Radioactive Waste Management, Study Plan No. 8.3.1.17.4.1, November 1991. [Prepared by the U.S. Geological Survey.]