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**COMPLIANCE DETERMINATION STRATEGY**
3.2.1.9 POTENTIALLY ADVERSE CONDITION-Evidence of Igneous Activity
[10 CFR 60.122(c)(15)]

PRIMARY REGULATORY CITATION:

10 CFR 60.21(c)(1)(ii)(B)

TYPES OF REVIEW:

Acceptance Review (Type 1)
Safety Review (Type 3)
Detailed Safety Review Supported by Analysis (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 is considered to be License Application-related because, as specified in the License Application content requirements of 10 CFR 60.21 and the Format and Content Regulatory Guide -- DG-3003 (NRC, 1990), it must be addressed by the DOE in its license application. Therefore, the staff will conduct an acceptance review of the License Application for this regulatory requirement.

Safety Review (Type 3) Rationale:
This regulatory requirement 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 (i.e., regulatory requirements in Subparts E, G, H, I, and 10 CFR 60.21). Therefore, the staff will conduct a safety review of the License Application to determine compliance with the Regulatory Elements of Proof for this regulatory requirement.

The Yucca Mountain site is located in an area of the Basin and Range physiographic province which has experienced extensive tertiary volcanic and magmatic activity of both silicic and basaltic affinities, and Quaternary basaltic volcanic activity has occurred near the site (DOE, 1988, pp. 1-88 - 1-99). Therefore, this potentially adverse condition exists for the Yucca Mountain site. There are also concerns about determining the degree to which the condition is present, or may be present and undetected.

Detailed Safety Review Supported by Analysis (Type 4) Rationale:
The staff considers that any finding made under this requirement may be highly uncertain and controversial due to the Key Technical Uncertainties discussed below. Therefore, projections concerning the potential for and effects of igneous activity during the period of intended performance will contain a large amount of uncertainty. This uncertainty could cause a

high risk of non-compliance with the overall system performance objective specified in 10 CFR 60.112.

The Key Technical Uncertainty associated with low resolution of exploration techniques is considered to require a Type 4 review for igneous activity because there is a high risk of non-compliance with the performance objective related to waste isolation. This high risk necessitates analyses above and beyond those required for Type 3 reviews to assure that the uncertainty, and the associated effects on performance, have been reduced to the extent possible.

Key Technical Uncertainty Topic: Low Resolution of Exploration Techniques to detect and evaluate igneous features.

Description of Uncertainty: Geologic conditions at the Yucca Mountain site render low resolution results from most geophysical techniques. For example, standard reflection and refraction techniques may produce poor records of the subsurface in the Yucca Mountain region because of problems related to transmitting sufficient energy through the rock units. Teleseismic tomographic techniques such as those used by Evans and Smith (1992) have resolution capabilities on the order of kilometers. In addition, if dikes are assumed to be the prevalent volcanic/magmatic feature in the region, their commonly vertical orientation would make them difficult to detect in the subsurface using standard vertical drilling techniques.

Many features which are presumed to have a bearing on understanding magmatic processes, such as the zone of possible partial melt of Evans and Smith (1992), cannot be sampled directly (see the Key Technical Uncertainty related to Inability to Sample Igneous Features) and therefore can only be evaluated through indirect measurements. In addition, many properties, such as heat flow, are known to have some relationship to igneous processing, but the exact relationship is poorly understood. Therefore, processes, features, and characteristics related to igneous activity have a degree of uncertainty which is difficult to quantify.

Performance Objective at Risk and Associated Regulatory Requirement: 10 CFR 60.112

Explanation of Nature of Risk: Magmatic activity is a process which, if it occurred, has the potential for causing non-compliance with 10 CFR 60.112 even without considering coupled effects or the effects of other processes and events. To date, most probability and consequence analyses, have not considered coupled effects, such as effects on groundwater flow and transport, which increase the risk of non-compliance with 10 CFR 60.112. Direct disruption of the repository has received the most attention even though this is a relatively low probability event. However, volcanic activity in the vicinity of the repository, with resultant effects on coupled processes, has a higher probability of occurring and may cause a significant change to the complementary cumulative distribution function (CCDF). The uncertainty

and risk associated with this Key Technical Uncertainty lies in the fact that determining the presence or absence of volcanic/magmatic features and processes, or determining the degree to which these features and processes may be present and undetected, could be severely impaired. In addition, little effort has been given to investigation and evaluation of the effects when the activity is not directly within the repository block. Therefore, understanding of the processes, features, and characteristics related to igneous activity, both direct and secondary, has a degree of uncertainty which is extremely hard to quantify.

Description of Resolution Difficulty: This uncertainty can best be addressed through the use of an integrated exploration program which employs multiple investigative techniques. In addition, various state-of-the-art techniques can be employed to improve the detection capabilities of the methods applied (Jones *et al.*, 1987). Although such procedures can minimize the uncertainty related to detection problems, some uncertainty will still be carried into subsequent analyses. If an integrated exploration program is not conducted by the DOE, the staff would consider this Key Technical Uncertainty to require a Type 5 review.

Detailed Safety Review Supported by Independent Tests, Analysis, or Other Investigations (Type 5) Rationale: Because the following Key Technical Uncertainties are the most difficult to resolve, they may pose the highest potential risk of non-compliance with the performance objective of 10 CFR 60.112. For these uncertainties, very little can be done to reduce the risk or compensate for the risk using, for example, favorable site conditions or engineering features.

Modeling exercises are already underway in an attempt to quantify and, reduce the uncertainty related to conceptual models. It is recognized that most of this modeling has and will be done under performance assessment. However, the interplay between performance assessment staff and geologists and volcanologists providing input cannot be stressed too strongly.

Key Technical Uncertainty Topic: Inability to Sample Igneous Features.

Description of Uncertainty: Many features related to volcanic/magmatic activity cannot be directly sampled. For example, the large low-velocity zone in the mantle, interpreted by Evans and Smith (1992) as a possible partial melt and the potential source for basaltic volcanism in Crater Flat, is known only from imaging by teleseismic tomography. This Key Technical Uncertainty stems from the fact that many features determined from low-resolution geophysical techniques cannot be sampled, so considerable judgment will be required in interpretation of anomalies detected by geophysical methods. The low velocity zone of Evans and Smith (1992), has several possible explanations, as does the seismic "bright spot" discussed by Brocher *et al.* (1990). In addition, other variables such as magma temperature and volatile content can only be constrained through detailed studies

of past eruptions. Key Technical Uncertainties may also exist relative to adequacy of age dating techniques for representing temporal distribution of volcanic/magmatic events.

Performance Objective at Risk and Associated Regulatory Requirement: 10 CFR 60.112

Explanation of Risk: Because of the inability to sample features, description of the characteristics of interpreted features is uncertain and can vary based on the model chosen. This means conceptual and mathematical models for use in performance assessment can never be completely verified or validated.

Description of Resolution Difficulty: As this problem is directly related to the amount of data available, the solution may involve use of subjective judgement in addition to objective data. Subjective judgement will be used to interpret the nature of the volcanic/magmatic features as well as for projecting the resultant effects of these features. The staff knows of no feasible technique to resolve the uncertainties related to inability to sample volcanic/magmatic features.

Key Technical Uncertainty Topic: Development and use of conceptual Tectonic Models as related to Igneous Activity.

Description of Uncertainty: The geologic data at Yucca Mountain are, and will most likely remain, permissive for the development of multiple geologic models to describe the presence and origin of many volcanic/magmatic and tectonic features. The choice of a conceptual geologic model can have a significant effect on interpretation of the hazards which may affect the repository. For example, currently available models include one assuming a northwest trending controlling structural feature (Crowe and Perry, 1990), and another assuming a north-northeast controlling structural feature (Smith *et al.*, 1990). These two models are mutually exclusive; however, existing data can be used to support either model. While it may be possible to determine a preferred model, the staff does not believe that either of these two models can be eliminated from consideration at the present time. The choice of one could strongly affect the results of performance calculations for assessing potential volcanic hazards in the vicinity of Yucca Mountain. Because of this range in permissible models and the associated uncertainties, this Key Technical Uncertainty is considered to involve a Type 5 review.

Performance Objective at Risk and Associated Regulatory Requirement: 10 CFR 60.112

Explanation 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 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 [10 CFR 60.122 (c)(15)]or the regulatory requirement related to overall system performance (10 CFR 60.122). Conceptual models can be used to describe the assumed physical and 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 igneous 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 final results from performance assessment analyses.

Description of Resolution Difficulty: The Key Technical Uncertainty related to conceptual models is considered to require a Type 5 review because very little can be done to reduce the risk of non-compliance. 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 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, related mainly to concerns about the inability to sample volcanic/magmatic feature and alternative conceptual models, can be summarized as follows:

(1) Quantitative knowledge about volcanic/magmatic processes in the Yucca Mountain area is, and most likely will remain, rudimentary for both the deep and shallow subsurface. The ability to substantially improve on this knowledge base will be severely hampered by the low-resolution capabilities of the exploration techniques and the inability to adequately sample volcanic/magmatic features.

(2) Alternative conceptual models of volcanic/magmatic processes may remain at the time of licensing.

(3) Alternative conceptual models linking volcanic/magmatic processes with tectonic activity may remain at the time of licensing.

(4) The alternative models for addressing probability of volcanic/magmatic activity and potential effects from this

activity may span orders of magnitude.

(5) The effects of volcanic/magmatic activity on the ability to demonstrate compliance with the overall system performance objective will be a highly contentious point during the hearing process.

REVIEW STRATEGY:

Acceptance Review (Type 1):
In conducting the acceptance review of the potentially adverse condition (PAC) concerning evidence of igneous activity, the reviewer should determine if the information presented in the License Application and its references for demonstrating compliance with the igneous activity PAC requirement is complete in technical breadth and depth as required by DG-3003 (NRC, 1990). All appropriate information necessary for the staff to review the likelihood and type of hazard posed by this PAC should be presented such that assessments required by the regulatory requirements associated with total system and subsystem performance objectives can be performed.

The information in the License Application should be presented in a manner such 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 also should be able to determine that information and appropriate alternative interpretations of controversial issues and models have been adequately described and considered.

Finally, the reviewer should determine if DOE has either resolved all the NRC staff objections to the License Application that apply to this regulatory requirement, or provided all information requested in Section 1.6 of DG-3003 (NRC, 1990) for unresolved objections. The reviewer should 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) on 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 is limited to consideration of evidence concerning igneous activity that has occurred in the area of the Yucca Mountain site. Although the regulatory requirement is limited to that activity which occurred since the start of the Quaternary Period, evidence of pre-Quaternary activity will require examination to demonstrate a sufficient understanding of igneous activity in the vicinity of the site. This regulatory requirement does not address projections of type, probability, and effects of igneous activity during the intended period of performance. These "projection" analyses will be covered in other review plans.

In conducting the safety review, as a minimum, the reviewer will, assess

the adequacy of the data and analyses presented in the License Application to determine the DOE's compliance with 10 CFR 60.21(c)(1)(ii)(B). Specifically, the DOE will be required to: (1) provide information to determine whether, and to what degree, the PAC is present; (2) provide information to determine to what degree the PAC is present, but undetected; (3) assure the sufficiency of the lateral and vertical extent of data collection; and (4) evaluate the information presented under (1) and (2), with assumptions and analysis methods that adequately describe the presence of the PAC and ranges of relevant parameters. For purposes of determining the presence or absence of this PAC, investigations should extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility, and to a depth sufficient to demonstrate a suitable understanding of igneous processes such that reasonable bounds can be placed on the different conceptual models. In general, the reviewer will assess the adequacy of the DOE's investigations of igneous activity, both within the site and the geologic setting, as necessary. The specific aspects of the license application on which the reviewer will focus are discussed in DG-3003 (NRC, 1990), and the acceptance criteria will be identified in Section 3 of the review plan.

To conduct an effective review, the reviewer will rely on personal expertise and independently-acquired knowledge, information and data such as the results of research activities being conducted by the NRC Office of Regulatory Research, in addition to that provided by the DOE in its License Application. For example, teleseismic data have indicated a large low velocity zone beneath the site, which could indicate, among other things, a zone of partial melting and a source for basaltic magma (Evans and Smith, 1992). The reviewer should peruse this geophysical information plus relevant data from follow-up studies to refine this information. It is incumbent upon the reviewer to have acquired knowledge regarding these and other critical considerations in anticipation of conducting the review to assure that the exploration program is sufficient in scope and depth to provide the information necessary to resolve the concerns.

Detailed Safety Review Supported by Analysis (Type 4): A detailed review will be needed for evaluation of the Key Technical Uncertainty regarding poor resolution capability of exploration techniques to determine and evaluate igneous features and processes. This will ensure that the DOE has adequately handled Items (1)-(4) listed above in the previous section (Safety Review, paragraph 2).

Examples of specific review activities that will be required include: (1) review and analysis of the geophysical tests which have been conducted in the vicinity of Yucca Mountain to assess the characteristics and distribution of volcanic/magmatic features; (2) review and analysis of results of field mapping programs to assess the distribution and characteristics of volcanic/magmatic features; (3) review of information provided by the drilling programs; and (4) review of the leveling and global positioning satellite (GPS) studies. The analysis should focus on the sensitivity, resolution and detection capabilities of the different techniques; and the degree to which the separate techniques can provide

independent assessments of the various features and characteristics of concern; and the degree to which the techniques provide information which either corroborates or contradicts results of the other techniques.

Detailed Safety Review Supported by Independent Tests, Analysis, or Other Investigations (Type 5) Rationale: A detailed safety review, independent modeling and the use of the results of staff investigations will be needed for the Key Technical Uncertainties related to conceptual models and the inability to sample igneous features. This will ensure that the DOE has adequately handled Items (1)-(4) listed in the section on safety review (Safety Review, paragraph 2).

For the Key Technical Uncertainties concerning development and use of conceptual tectonic models and the inability to sample igneous features, the staff detailed review will be supported by conceptual and numerical models developed by the staff through Iterative Performance Assessment to determine if models being used by the DOE provide an adequate explanation of the phenomenon of igneous activity. Independent field investigations and laboratory analyses may be required to support the conceptual and numerical models. 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. For example, while it is generally accepted that detachment faults are present in the area of Yucca Mountain, the models proposed to date do not provide an adequate explanation of the relationship between conduits for volcanic activity and the detachment. Through various modeling exercises, the staff may develop a range of structural models and attempt to determine the relationships necessary for dikes to be propagated through the structures.

When reviewing and creating models, it should be recognized that, in addition to field and analytical data, subjective judgement will also be required. It is important that the assumptions necessary for the different models be carefully documented and thoroughly reviewed. Bounding assessments, field data; and the results of research activities should be included to narrow and distinguish between the 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 undetected due to the limitations of the methods applied. The staff must also assure that the models used incorporate all appropriate field data and assumptions.

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APPLICABLE REGULATORY REQUIREMENTS:

Type 3:

10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.112
10 CFR 60.122(c)(15)

Type 4:

10 CFR 60.21(c)(1)(ii)(B),(C), & (F)
10 CFR 60.112
10 CFR 60.122(c)(15)

Type 5:

10 CFR 60.21(c)(1)(ii)(B),(C), & (F)
10 CFR 60.112
10 CFR 60.122(c)(15)

REFERENCES:

Brocher, T.M., P.E Hart, and S.F. Carle, "Feasibility Study of the Seismic Reflection Method in Amargosa Desert, Nye County, Nevada," United States Geological Survey, Open File Report 89-133, 1990.

Crowe, B.M., and F.V. Perry, "Volcanic Probability Calculations for the Yucca Mountain Site: Estimation of Volcanic Rates," in "Nuclear Waste Isolation in the Unsaturated Zone -- FOCUS '89," American Nuclear Society, *Proceedings of the Topical Meeting*, September 17-21, 1989, Las Vegas, Nevada, pp. 326 - 334 [1990].

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.

Evans, J.B., and M. Smith, III, "Teleseismic Tomography of the Yucca Mountain Region: Volcanism and Tectonism," in "High-Level Radioactive Waste Management," American Society of Civil Engineers/American Nuclear Society, *Proceedings of the Third Annual International Conference, April 12-16, 1992,* Las Vegas, Nevada, Vol. 2, pp. 2372-2380.

Jones, G.M., M.E. Blackey, J.E. Rice, M.V. Murphy, E.N. Levine, P.S. Fisk, and R.W. Bromery, "Survey of Geophysical Techniques for Site Characterization in Basalt, Salt, and Tuff," Nuclear Regulatory Commission, NUREG/CR-4957, July 1987.

Smith, E.I., D.L. Feuerbach, T.R. Naumann, and J.E. Faulda, "The Area of Most Recent Volcanism Near Yucca Mountain, Nevada: Implications for Volcanic Risk Assessment," in "High-Level Radioactive Waste Management," American Society of Civil Engineers/ American Nuclear Society, *Proceedings of the International Topical Meeting, April 8-12, 1990,* Las Vegas, Nevada, pp. 81-90.

Nuclear Regulatory Commission, "Draft Regulatory Guide DG-3003: Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research, November 1990.

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.