COMPLIANCE DETERMINATION STRATEGY
RRT 3.2.1.9 POTENTIALLY ADVERSE CONDITION: EVIDENCE OF IGNEOUS ACTIVITY (SINCE START OF THE QUATERNARY PERIOD)

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.31(a)(1)(i)
10 CFR 60.31(a)(2)
10 CFR 60.112
10 CFR 60.122(c)(15)

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 topic (RRT) is considered to be license application-related because, as specified in the license application content requirements of 10 CFR 60.21(c) and in the regulatory guide of the U.S. Nuclear Regulatory Commission (NRC) on "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 of 10 CFR 60). Therefore, the staff will conduct a safety review of the license application to determine compliance with this regulatory requirement topic.

The regulatory requirement topic is concerned with a potentially adverse condition (PAC), evidence of igneous (i.e., volcanic and magmatic) activity since the start of the Quaternary Period, and focuses on characterization of the Yucca Mountain site by DOE in relation to igneous activity. For regulatory purposes, the Quaternary Period is defined as the last 2 million years (NRC, 1983, p. 373).

The Yucca Mountain site is located in an area of the Basin and Range physiographic province which experienced extensive volcanic and magmatic activity of both silicic and basaltic affinities and tectonic deformation during the Cenozoic Era (i.e., the last 63 million years). During the Quaternary Period of

the Cenozoic (i.e., the last 2 million years), basaltic volcanic activity has occurred near the site (DOE, 1988, pp. 1-88 - 1-99). Therefore, this PAC is known to exist for the Yucca Mountain site. Furthermore, concerns also exist about determining the degree to which the PAC is present at the site, and the degree to which it may be present and undetected.

Detailed Safety Review Supported by Analysis (Type 4) Rationale:

Any finding made under this regulatory requirement topic may be considered highly uncertain due to the Key Technical Uncertainty (KTU), discussed below, related to low resolution of exploration techniques for detection and evaluation of igneous features. Therefore, projections concerning the potential for and effects of volcanic and magmatic activity during the period of intended performance may contain a large amount of uncertainty, which could cause a high potential 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 because there is a high potential risk of non-compliance with the performance objective, stated below, from 10 CFR 60.112. This concern about high risk of non-compliance will necessitate analyses above and beyond those required for a Type 3 review to assure that the uncertainty, and the associated potential effects on performance, have been minimized 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 transmission of 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 igneous feature in the region, the fact that they are commonly vertical makes them difficult to detect in the subsurface using standard vertical drilling techniques.

Because many features which are presumed to bear a relationship to magmatic and volcanic processes are deep-seated and cannot be sampled directly, the use of exploration techniques is required for their investigation. One example of such a feature is the low velocity feature described by Evans and Smith (1992) which underlies Crater Flat at lower crustal depths, for which they suggest one possible interpretation as a zone of partial (basaltic) melt beneath Crater Flat. Clearly, such features can be evaluated only through indirect measurements and development of alternative interpretations. (See also the Key Technical Uncertainty related to inability to sample igneous features under the discussion of Type 5 rationale.) In addition, many properties (e.g., heat flow) are known to bear a relationship to volcanic and magmatic processes, but the exact relationship is poorly understood at present. Consequently, processes, features and characteristics related to igneous activity possess a degree of uncertainty in adequately understanding them which can be very difficult to quantify.

Performance Objective at Risk: Total System Performance Objective (10 CFR 60.112)

Explanation of Nature of Risk: Igneous 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 of igneous activity 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 and magmatic 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 may be 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 detection capabilities (Jones *et al.*, 1987). Although such an approach may minimize the uncertainty related to detection problems, at least some uncertainty related to detection of features will still be carried into subsequent analyses. If an integrated exploration program for investigation of volcanic/magmatic features is not conducted by DOE, the staff will 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 two Key Technical Uncertainties presented below are the most difficult to resolve, they are considered to pose the highest potential risk of non-compliance with the performance objective of 10 CFR 60.112 for the Yucca Mountain site. For these uncertainties, very little can be done to reduce or compensate for the risk using favorable site conditions or engineered components. The potential for high residual risk of non-compliance in light of these Key Technical Uncertainties is sufficient to justify a detailed safety review supported by independent tests, analyses, or other investigations (Type 5).

Key Technical Uncertainty Topic: Inability to Sample Igneous Features

Description of Uncertainty: Many features related to volcanic/magmatic activity cannot be directly sampled. This Key Technical Uncertainty stems from the fact that many features determined from low-resolution geophysical techniques cannot be sampled, so that considerable judgment will be required in interpretation of anomalies detected by geophysical methods.

For example, the low-velocity feature in the lower crust-upper mantle, interpreted by Evans and Smith (1992) as a possible zone of partial melt and the potential source for basaltic volcanism in Crater Flat, is known only from imaging by teleseismic tomography. While Evans and Smith (1992) favor this interpretation, they are careful to point out that this low velocity zone may be interpreted in other ways as well. Another example is seen in data discussed by Brocher *et al.* (1990) which indicate a seismic "bright spot" in the lower crust beneath the Amargosa Desert at a location south of Yucca Mountain. This high-amplitude reflection may be interpreted, by analogy with records from other locations, as reflections from thin, discontinuous magma chambers. Brocher *et al.* (1990) are also careful to indicate that other interpretations of their data are both possible and reasonable. In addition, other variables (e.g., magma

temperature and volatile content) can be constrained only through detailed studies of past eruptions. It may be determined that Key Technical Uncertainties also exist in relation to adequacy of age dating techniques for accurately representing temporal distribution of volcanic/magmatic events.

Performance Objective at Risk: Total System Performance Objective (10 CFR 60.112)

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

Description of Resolution Difficulty: Since this problem of the inability to sample igneous features is directly related to the amount of data available, the solution may involve use of subjective judgement in addition to objective data. Subjective judgement may be used to interpret the nature of the volcanic/magmatic features, as well as for projecting the potential resultant effects of these features. The staff knows of no feasible technique to resolve the uncertainties related to the 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 can be viewed as mutually exclusive, although existing data can be used to support either model. While it may be possible to determine a preferred model, the staff recommends that neither of the two 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 the range in permissible models and the associated uncertainties, this Key Technical Uncertainty is considered to involve a Type 5 review.

Performance Objective at Risk: Total System Performance Objective (10 CFR 60.112)

Explanation of Nature of Risk: By definition, models are a simplification of reality. Moreover, both conceptual and mathematical models will be used in the high-level waste program for analysis of site and repository performance. The conceptual model(s) selected can have a significant effect on scope of the field investigation program and on interpretation of the data obtained. In addition, the regulatory requirement topic 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 PAC (i.e., 10 CFR 60.122 (c) (15)) or the regulatory requirement related to overall system performance (i.e., 10 CFR 60.112). 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 can be used in performance assessment to "predict" the behavior of the system.

Because it is impossible to completely sample and describe a physical system which is as complex as that represented by igneous activity in the vicinity of Yucca Mountain, uncertainties exist both in data and parameters in relation to this PAC. Because of these uncertainties, there will be an inherent uncertainty in the level of understanding of the physical system being represented by the model(s), 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.

Modeling exercises are already underway which are attempting to quantify and reduce the uncertainty related to conceptual models. Although it is recognized that most of this modeling has and will be done under performance assessment, interchange between performance assessment staff and geologists and volcanologists providing input cannot be stressed too strongly.

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 requirement, related mainly to concerns about the inability to sample volcanic/magmatic features and use of alternative conceptual tectonovolcanic 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 and events 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 several orders of magnitude in the numerical values of probability.

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

REVIEW STRATEGIES:

Acceptance Review

In conducting the acceptance review of the PAC concerning evidence of igneous activity since the start of the Quaternary Period, the reviewer should determine if the information presented in the license application and its references for demonstrating compliance with regulatory requirements germane to this PAC is complete in technical breadth and depth as required in the regulatory guide on "Format and

Content for the License Application for the High-Level Waste Repository" (FCRG). (As indicated in NUREG-0804 (NRC, 1983, p. 373), for regulatory purposes the Quaternary Period is defined as the last 2 million years.) Likewise, the reviewer should determine that all appropriate information necessary for the staff to review the likelihood and type of hazard posed by this PAC is presented, such that assessments required by the regulatory requirements associated with total system and subsystem performance objectives can be performed.

The reviewer should determine whether the information in the license application is 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 determine that controversial 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 NRC staff objections that apply to this regulatory requirement topic, or provided all information requested in Section 1.6.2 of the FCRG 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) the ability of the Commission to make a decision regarding construction authorization within the three-year statutory period.

Safety Review:

This regulatory requirement topic is limited to consideration of evidence concerning igneous activity that has occurred in the vicinity of the Yucca Mountain site since the start of the Quaternary Period. Although the regulatory requirement topic is limited to activity which occurred during the Quaternary, 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 topic 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. The specific aspects of the license application on which the reviewer will focus are discussed in the FCRG, and the acceptance criteria will be identified in Section 3.0 of review plan 3.2.1.9 in the LARP.

In conducting the safety review, the reviewer should determine if the information presented in the license application and its references is an acceptable demonstration of compliance with the applicable regulatory requirements. At a minimum, the reviewer should assess the adequacy of the data and analyses presented in the license application to support DOE's demonstration regarding 10 CFR 60.122(c)(15). 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 Items (1) and (2) as stated above, with assumptions and analysis methods that adequately describe the presence of the PAC and ranges of relevant parameters. In general, the reviewer will assess the adequacy of DOE's investigations of this PAC, both at the site and in the geologic setting, in the manner outlined in 10 CFR 60.21(c)(1)(ii)(B). 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.

DOE will also need to provide an explanation of the measures applied to assess the presence or absence of evidence for igneous activity. Analyses and models used to predict future conditions and changes in the geologic setting should be supported by an appropriate combination of field, in-situ, and laboratory tests which provide data representative of field conditions.

In conducting the safety review, the reviewer should determine whether DOE uses both analyses sensitive to evidence of effects of structural deformation on volcanic/magmatic processes and events, and assumptions which are not likely to underestimate evidence of igneous activity during the Quaternary Period. In general, the reviewer should assess the adequacy of DOE's investigations of evidence of igneous activity, both within and outside the controlled area, as necessary.

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 Office of Regulatory Research, in addition to that provided by 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 a body of knowledge regarding these and other critical considerations in anticipation of conducting the review to assure that the igneous activity exploration program of the DOE 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 in this review to address the presence (or absence) of this PAC:

Study Plan No.	*Title*
8.3.1.8.1.1	*Probability of Magmatic Disruption of the Repository*
8.3.1.8.5.1	*Characterization of Volcanic Fractures*

Detailed Safety Review Supported by Analysis

A detailed safety review and analysis will be needed for evaluation of the Key Technical Uncertainty regarding low resolution capability of exploration techniques to determine and evaluate igneous features and processes. This will ensure that DOE has adequately demonstrated Items (1)-(4), listed in the above discussion of the review strategy for a safety review. Activities performed in the detailed safety review will help assure that DOE has adequately addressed and resolved this Key Technical Uncertainty so that it does not lead to noncompliance with the total system performance objective of 10 CFR 60.112.

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; 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. It may also be appropriate to assess the quality and traceability of data and information by using staff with specific expertise in the review of quality assurance programs.

Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations 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 DOE has adequately demonstrated Items (1)-(4), listed in the above discussion of the review strategy for a safety review.

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 DOE provide an adequate explanation of the phenomenon of igneous/magmatic activity. Independent field investigations and laboratory analyses may be required to support the conceptual and numerical models. In conducting this review, the staff should 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 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 detection methods applied. The staff must also determine whether the models used incorporate all appropriate field data and assumptions.

In view of complexities associated with the two Key Technical Uncertainties which necessitate a detailed safety review supported by independent tests, analyses, and other investigations, it is appropriate that the NRC conduct the independent activities described above to accomplish the following: (1) Develop the licensing tools and technical basis necessary for judging the adequacy of DOE's license application; (2) assure sufficient independent understanding of the basic physical processes taking place at the geologic repository; and (3) maintain independent, but limited, confirmatory research capabilities under the auspices of the NRC.

Contributing Analysts:

NRC: J.S. Trapp

CNWRA: G.L. Stirewalt and S.R. Young

Date of Analysis: September 11, 1992

APPLICABLE REGULATORY REQUIREMENTS FOR EACH REVIEW TYPE

Type 1:
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.31(a)(1)(i)
10 CFR 60.31(a)(2)
10 CFR 60.112
10 CFR 60.122(c)(15)
Type 3:
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.31(a)(1)(i)
10 CFR 60.31(a)(2)
10 CFR 60.122(c)(15)
Type 4:
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.112
10 CFR 60.122(c)(15)
Type 5:
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(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. Faulds, "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.

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. Nuclear Regulatory Commission, "Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, Disposal of High-Level Radioactive Waste in Geologic Repositories," Office of Nuclear Regulatory Research, NUREG-0804, December 1983.

U.S. Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository" (FCRG), Office of Nuclear Regulatory Research.

U.S. Nuclear Regulatory Commission, "License Application Review Plan for the Review of a License Application for a Geologic Repository for Spent Nuclear Fuel and High-Level Radioactive Waste, Yucca Mountain, Nevada" (LARP), Office of Nuclear Material Safety and Safeguards.