COMPLIANCE DETERMINATION STRATEGY
RRT 3.2.4.1 - FAVORABLE CONDITION: PRECIPITATION THAT IS A SMALL PERCENTAGE OF AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION

1.0 APPLICABLE REGULATORY REQUIREMENTS

10 CFR 60.21(c)(1)(ii)(A)
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(b)(8)(v)

TYPES OF REVIEW

Acceptance Review (Type 1)
Safety Review (Type 3)

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 the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG), it must be addressed by 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 is related to waste containment and 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 focuses on whether the site is located in a climatic regime where the average annual historic precipitation is a small percentage of the average annual potential evapotranspiration (PE). The staff considers the term "historic" to refer to the relatively recent period for which precipitation and temperature records are available for the region of the site. Specifically, this favorable condition requires an assessment of modern-day precipitation and potential evapotranspiration at Yucca Mountain. Because the assessment must be based on historic data, the staff does not expect DOE under this topic to estimate future climate change or to collect and evaluate paleoclimatic data to assess this favorable condition. The staff does expect a thorough evaluation of this recent record of past precipitation in the Yucca Mountain region. In analyzing the data, DOE must take into account the fact that meteorological stations existed at varying elevations in the region. Although DOE must estimate "potential" evapotranspiration to evaluate the presence or absence of this favorable condition, it is not necessary to determine "actual" rates of evapotranspiration at the Yucca Mountain site. However, "actual" evapotranspiration must be evaluated under other review plans that address infiltration studies to estimate percolation, recharge, and groundwater travel time in the unsaturated zone.

The expression "potential evapotranspiration" (PE) has been clarified by the staff. The staff accepts the definition of PE as discussed in the National Handbook of Recommended Methods for Water-Data Acquisition (USGS, 1982, p. 8-39). PE is defined as:

> "... the rate of water loss from a wet soil or well-watered, actively growing vegetation, or as the rate of evaporation from a water surface."

The "Handbook" continues with the following discussion:

> "These [rates] may not be the same. Investigators should not report potential evapotranspiration without describing the surface involved in the measurements or for which the estimates are provided, nor should one compare reported values of potential evapotranspiration without first considering the character of the surface to which the values apply."

Various methods exist to estimate PE. Pan evaporation can be used, and this is discussed below. The empirical method of Thornthwaite (1948) can provide a good estimate of PE given only the latitude of a location and records of mean monthly air temperature. With a few exceptions in humid (especially tropical) areas, this method is reported to give reasonable results in a variety of climatic extremes, and Carter and Mather (1966, p. 326) consider that it is as useful as any method for estimating average PE. Evapotranspirometer tanks (containing well-watered soil and plants) have also been used.

The use of pan evaporation data to estimate PE has sometimes been viewed with skepticism. Thornthwaite and Mather (1955, p. 17) stated that "...water loss from ordinary evaporation pans or soil tanks can be very different from the true potential evapotranspiration." They also stated that "...pan evaporation is strongly influenced by the moisture content of the air, and so it is not possible to determine potential evapotranspiration from pan evaporation." Thornthwaite and Mather (1955, p. 17) concluded that in "dry climates or during periods of drought, pan evaporation is always higher than potential evapotranspiration." This is mainly caused by heat storage effects within the pan. However, rates of free-water surface (FWS) evaporation can be computed by compensating for these heat storage effects by using meteorological factors and Class A evaporation pans equipped to measure water temperatures (Farnsworth, et al., 1982, p. 4). FWS evaporation is defined as evaporation from a thin film of water having no appreciable heat storage (Farnsworth, et al., 1982, p. 4). FWS evaporation closely represents the potential evaporation from well-watered natural surfaces, and is "...considered a good index to potential evapotranspiration or potential consumptive use" (Farnsworth, et al., 1982, p. 1). Dunne and Leopold (1978, p. 103 & 128) state that evaporation pans, such as the Class A pan, provide a good means of estimating PE, and "probably provide the best method of obtaining an index of potential evapotranspiration."

The staff considers that it will be acceptable for DOE to estimate average annual PE using rates of average annual FWS evaporation, and to compare this estimate to one obtained using Thornthwaite's (1948) empirical method (and any other optional methods). FWS evaporation is a more readily obtainable and verifiable measurement than the rate of water loss from a wet soil or from well-watered, actively growing vegetation. In fact, as discussed in the "Handbook" (USGS, 1982, p. 8-47), "[A] method has yet to be devised that provides an actual measurement of transpiration from any significant area of plant-covered land." "The process...is subject to enormous variation, temporal as well as spatial, over most plant-covered landscapes, so that measurements must be extrapolated to areal estimates very cautiously." The use of FWS evaporation is reasonable because the favorable condition in 10 CFR 60.122(b)(8)(v) refers to a "climatic regime in which the average annual historic precipitation is a small percentage of the average annual potential evapotranspiration." The favorable condition refers to a "climatic regime," which is more readily evaluated using meteorologic parameters rather than land surface characteristics.

Based on the above considerations, a conventional analysis of meteorological data will meet the intent of the requirements. The techniques to determine FWS evaporation, to apply the Thornthwaite (1948) method, and to document the historical precipitation record are well-established and are not known to contain any key technical uncertainties. Staff consider that DOE's estimate of average annual historic precipitation should be based on all the years of available data from stations in southern Nevada, especially those stations within about 100 km of the Yucca Mountain site. The value of average annual historic precipitation used to represent Yucca Mountain should be derived considering the range of elevation and topographic conditions at the site. Most nearby meteorological stations, such as the one that existed in Beatty, Nevada, occur at lower altitudes and would likely have received less precipitation. Unless the precipitation amount is adjusted for altitudinal differences, data from such stations would probably underestimate the average precipitation that has occurred at Yucca Mountain during the historical period of record. According to DOE (1988, p. 5-47), precipitation data exist for weather stations scattered throughout the western U.S., with record lengths of up to 100 years. It is known that FWS evaporation significantly exceeds precipitation at the Yucca Mountain site (see preliminary estimates given below), but details of this relationship for the Yucca Mountain site are not well-documented and would be the primary compliance demonstration information to be presented by DOE in the License Application.

Farnsworth et al. (1982) presents a map of average annual FWS evaporation for the continental United States. As shown on this map, values of FWS evaporation in southern Nye County, Nevada range from 50 inches (127 cm) to more than 75 inches (190 cm) per year. DOE (1991) cites French's (1986) analysis of the relationship between precipitation and topographic elevation in southern Nevada. French used a linear regression model and a sample of 63 precipitation stations to calculate a gradient of 28 mm of average annual precipitation per 1000 vertical ft. For a sample of 12 stations on the Nevada Test Site with data records covering 10 years or more, French (1986) calculated a gradient of 38 mm/1000 ft.

Topographic elevations at the site range from about 4000-4950 ft. Using French's (1986) 10-year precipitation data from the Nevada Test Site (38mm/1000 ft) and an elevation of 5000 ft yields an average yearly precipitation of 190 mm, or 19.0 cm. Now the estimate of average yearly precipitation can be compared to the reported range of average annual FWS evaporation in southern Nevada (Farnsworth et al., 1982). This information suggests that the precipitation varies from about 10% to 15% of the estimated FWS evaporation.

DOE (1988, p. 3-8) reported an annual average PE in the range of 150 to 170 cm/yr for the region that includes Yucca Mountain. An average annual precipitation of about 15 cm was also reported. Based on these numbers, the average annual precipitation is about 10% of the annual average PE, a number comparable to the estimate calculated above.

Czarnecki (1990) performed measurements of evapotranspiration (ET) using various methods at Franklin Lake Playa, which is an extensive groundwater discharge and phreatophyte area located 65 km south of Yucca Mountain. He documented a program of field investigations conducted between June 1983 and April 1984. Czarnecki concluded that the most reasonable and representative estimates of ET at Franklin Lake Playa were obtained using the energy-balance eddy correlation technique. The following data were obtained from Table 22 of Czarnecki, 1990 (p. 79):

SUMMARY OF EVAPOTRANSPIRATION ESTIMATES FROM ALL TECHNIQUES USED
(STUDY AT FRANKLIN LAKE PLAYA)

TECHNIQUE	EVAPOTRANSPIRATION ESTIMATE (cm/day)
Energy-balance eddy correlation	0.1 to 0.3
Empirical potential evapotranspiration relations:	
Lower range (January)	0.1 to 0.5
Upper range (July)	0.5 to 1.7
Temporal changes in soil-moisture content in the unsaturated zone	Inconclusive -0.07 to 0.1
Evapotranspiration by phreatophytes (Robinson, 1958[1], measurements made in climatically similar Owens Valley and Santa Ana, California, along with other locations)	0.09 to 0.34
Temperature profiles	Inconclusive
Saturated-zone vertical gradients	0.06 to 0.5
One-dimensional finite-difference model	0.06

{[1] Reference believed to be Robinson, 1957.}

The data in the above table can be compared to an estimate for annual rainfall at Franklin Lake Playa. Czarnecki (1990, p. 46) cites Winograd and Thordarson (1975) in estimating a rainfall of 5 cm/yr at the playa. Then, using the data from the method (eddy correlation) that Czarnecki (1990) considered to be most representative, the 5 cm/yr annual rainfall at Franklin Lake Playa would be a relatively small percentage (4% - 14%) of the ET values determined at Franklin Lake Playa (35 to 110 cm/yr). Overall, Czarnecki's (1990) work illustrated the difficulties encountered in directly measuring ET even in an active discharge area.

The following assumptions have been made in developing this rationale and assigning a Type 3 level of review (Safety Review) to this review plan topic:

1. No key technical uncertainties have been identified with regard to this favorable condition. It is expected that DOE can evaluate the presence or absence of this condition in a straightforward way by documenting current and historical meteorological conditions in the vicinity of Yucca Mountain.

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2. The estimated range of average annual FWS evaporation in southern Nevada provides a reasonable approximation of average annual potential evapotranspiration for the region.

2.0 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

This regulatory requirement topic is limited to considering DOE's demonstration, through appropriate investigations, of the degree to which average annual historic precipitation is a small percentage of average annual potential evapotranspiration. This favorable condition concerns an assessment of the modern-day climatic regime. It is not concerned with future projections of climate, which are covered in Section 3.2.4.2 (PAC: Changes to Hydrologic System from Climate"), nor is it relevant to studies of paleoclimatic conditions. Findings under this review plan will provide input to other review plans (see Section 4.2.2).

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 60.21(c)(1)(ii)(A)(B) and (F) as they relate to 10 CFR 60.122(b)(8)(v). The specific aspects of the license application on which the reviewer will focus are discussed below. The Acceptance Criteria are identified in Section 3 of this review plan. Specifically, DOE should have (1) assessed whether and to what extent this favorable condition is present (i.e., that average annual historic precipitation is a small percentage of average annual potential evapotranspiration); (2) evaluated the extent to which the presence of this favorable condition may have been overestimated or undetected, taking into account the degree of resolution achieved by the investigations; (3) assured that the lateral and vertical extent of field data collection is sufficient to support items (1) and (2); and (4) further evaluated the information presented under items (1) and (2), using assumptions and analysis methods that encompass the ranges of all relevant parameters.

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In conducting the aforementioned evaluations, the reviewer should determine whether DOE used: (1) analyses that are sensitive to evidence of whether the favorable condition is present or absent; and (2) assumptions that are not likely to overestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations for evidence of this favorable condition, both within the controlled area and outside the controlled area, as necessary, in the manner outlined in 10 CFR 60.21(c)(1)(ii)(B).

To conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data in addition to that provided by DOE in its license application. The reviewer should focus on additional data which can refine knowledge of this favorable condition, and should acquire, as necessary, additional information to confirm the resolution capabilities of the methodologies. The reviewer must acquire a body of knowledge regarding these and other critical considerations in anticipation of conducting the Safety Review to assure that DOE's submittal is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

RATIONALE FOR REVIEW STRATEGY

Not Applicable.

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APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW

Type 1

10 CFR 60.21(c)(1)(ii)(A)
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(b)(8)(v)

Type 3

10 CFR 60.21(c)(1)(ii)(A)
10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(b)(8)(v)

6.0 REFERENCES

References for Rationales

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References for Review Strategies

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 Waste Management to identify the most current edition of the FCRG in effect.]