2/18

COMPLIANCE DETERMINATION METHOD FOR REVIEW PLAN NO. 3.2.4.1 FAVORABLE CONDITION: PRECIPITATION THAT IS A SMALL PERCENTAGE OF POTENTIAL EVAPOTRANSPIRATION

3.0 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the License Application (LA) concerning precipitation and potential evapotranspiration with the corresponding section of the FCRG and with the staff's resolution status of objections to LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at the staff level, the NRC objections to LA submittal that apply to this regulatory requirement topic, or provided all information requested in Section 1.6 of the FCRG for unresolved objections, namely, DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection
- Described all attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60

(3) In addition, unresolved objections, individually or in combination with others, will not prevent the reviewer from conducting a meaningful Compliance Review and the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for the following Compliance Review have been met. The results of the compliance determinations shall be documented by the staff to provide the basis for actual Evaluation Findings documented in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F), and 10 CFR 60.122(b)(8)(v)

This Safety Review shall be conducted only if the DOE asserts that the favorable condition regarding precipitation as a small percentage of potential evapotranspiration (PE) (i.e., climatic moisture) is present at the Yucca Mountain site. If DOE does not assert that this favorable condition is present, then no Safety Review will be necessary and the staff shall document a negative finding (see Section 5.2).

The staff will determine whether the assessment of presence or absence of the favorable condition on precipitation and PE has been accomplished in an acceptable manner, and whether the description of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(b)(8)(v). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support DOE's analysis of the meteorology of the site as related to precipitation and PE and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(b)(8)(v). For 10 CFR 60.21(c)(1)(ii)(B), the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses of the degree to which this favorable condition has been characterized and found to be present. The staff will review and evaluate information provided by DOE in the LA to demonstrate either the presence of this favorable condition, or the extent to which its presence may have been overestimated or undetected, taking into account the degree of resolution achieved by the investigation. The staff will also determine whether the analyses and investigations have been accomplished in an acceptable manner and whether lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(b)(8)(v). For 10 CFR 60.21(c)(1)(ii)(F), the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses and models used to investigate PE and precipitation. The staff will also determine whether the analyses and models are properly supported by an appropriate combination of methods such as field and laboratory tests, monitoring data, or natural analog studies for assisting review of 10 CFR 60.122(b)(8)(v).

To make compliance determinations for these Acceptance Criteria, the staff must review the results of site characterization and analyses conducted by DOE. This review is discussed below under Subsections 3.2.1.1 and 3.2.1.2 of this review plan. These subsections present review procedures and Acceptance Criteria related to PE and precipitation at the Yucca Mountain site.

3.2.1.1 Meteorologic and Climatologic Information for the Yucca Mountain region

To begin the Safety Review, staff must be familiar with and review the breadth and applicability of meteorological and climatological data for the Yucca Mountain site and the region of southern Nevada. This information is described below, and provided from those parts of the LA listed in Section 4.2.1 of this review plan:

- Historical data on the climatology and meteorology of southern Nevada, with particular emphasis on historical precipitation data
- Meteorological data from the Yucca Mountain site, including annual and monthly averages for temperature, precipitation, evaporation, humidity, wind patterns, and other appropriate meteorological data
- Maps showing the locations of data collection points used in the analyses, such as meteorological stations and precipitation gages, with respect to topography
- Precipitation and temperature data covering the historical period of data collection in southern Nevada

The Acceptance Criterion is that all of the above types of information must be presented in sufficient detail to provide and adequate understanding of the site.

3.2.1.2 Review Procedure for Average Annual Precipitation as a Small Percentage of Average Annual Potential Evapotranspiration

DOE can acceptably show that this Favorable Condition is present if supporting analyses show that average annual historic precipitation is 33 percent or less than the amount of average annual potential evapotranspiration (see Rationale in Section 3.3).

Step 1 -- Review Estimates for Average Annual Historic Precipitation for the Yucca Mountain Climate Regime

DOE's estimates of average annual historic precipitation for the climate regime shall be acceptable to the staff if the following Acceptance Criteria are met:

- Precipitation estimates are based on available precipitation data from meteorological stations that are located within about 100 km of Yucca Mountain. DOE (1988, p. 5-4 to 5-6) provided information on meteorological stations in the vicinity of Yucca Mountain. Precipitation data were collected at the Beatty monitoring station from 1931 to 1960. This station apparently provides the earliest precipitation data in the vicinity of Yucca Mountain. The next oldest set of records with which the staff is familiar date from 1957 through 1967, collected at a station on the Nevada Test Site.

- Documentation of the DOE search for data is sufficient to provide reasonable assurance that the search was exhaustive. [Note: Even though extensive precipitation data are being collected at the Yucca Mountain site, those data will not be representative of average annual historical conditions for the climate regime. The site measurements are not widespread enough to define the climate regime and the period of record has been too short. Precipitation data vary considerably on both spatial and temporal scales. For this reason, averages based on a reasonably large region with good coverage through time are appropriate.]

- Estimates of average annual historic precipitation used to characterize the Yucca Mountain climate regime have been appropriately corrected for the range of land surface elevations at the data collection sites.

Step 2 -- Review Estimates of Average Annual Potential Evapotranspiration for Yucca Mountain

DOE's estimates of average annual potential evapotranspiration (PE) at Yucca Mountain shall be acceptable to the staff if the following Acceptance Criteria are met:

- DOE has used the definition of PE from the National Handbook of Recommended Methods for Water-Data Acquisition (USGS, 1982, p. 8-39):

  > "Potential evapotranspiration 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** [emphasis added]."

5/18

- DOE has used the average annual rate of evaporation from a water surface, also known as free water surface (FWS) evaporation, to estimate the modern-day rate of average annual PE. Estimates of Yucca Mountain FWS evaporation are obtained from meteorological stations at the Yucca Mountain site, and these are compared to longer-term regional data from the National Weather Service (Farnsworth et al., 1982). For a conservative estimate, the data set (site vs. regional) that has the smaller rate should be reported as the average rate of annual FWS evaporation.

- DOE has obtained an estimate of average annual PE for Yucca Mountain using either the empirical method of Thornthwaite (1948) or a comparable method.

Step 3 -- Compare Average Annual Precipitation to Average Annual Potential Evapotranspiration

Staff will compare DOE's estimate of average annual historic precipitation to the average annual PE. Staff must ensure that the PE estimate is the smallest obtained by any method (i.e., from FWS evaporation, the empirical method of Thornthwaite (1948), and any other relevant methods). If the precipitation value, as a percentage of the PE value, is 33 percent or less, then the Favorable Condition is present. Otherwise, the Favorable Condition is absent. Staff will document a corresponding Evaluation Finding in Section 5 of this review plan.

If DOE has acceptably demonstrated that average annual historic precipitation is a small percentage of average annual potential evapotranspiration, then staff can have reasonable assurance that the following have been satisfied:

(1) Assumptions and analysis methods, used by DOE to evaluate the information presented determine the absence or acceptably describe the presence of the favorable condition and encompass appropriate ranges of relevant parameters.

(2) DOE can demonstrate that the extent of characterization is sufficient to define evapotranspiration in the geologic setting.

(3) DOE can demonstrate that the scope of investigations has bounded the range of conceptual models supported by the available data.

(4) DOE investigations at the site and in the geologic setting have been conducted in sufficient detail to assure that the benefits of this favorable condition are well enough understood to be appropriately considered in performance assessment and design.

(5) Results of DOE investigations are not in conflict with published results from various staff investigations or other independent studies, or the conflicts are adequately explained.

3.3 Rationale For Review Procedures and Acceptance Criteria

3.3.1 Rationale for Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F), and 10 CFR 60.122(b)(8)(v)

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 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-

6/18

day precipitation and potential evapotranspiration at Yucca Mountain. The staff expects 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. The staff does not expect DOE to collect and evaluate paleoclimatic data in assessing this favorable condition. 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 will be evaluated under other review plans (e.g. 3.2.2.1, 3.2.2.4, 3.2.2.9, and 3.2.2.12) 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 not always been viewed with optimism. 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.

In developing Acceptance Criteria for the review methods in Section 3.2.1, the staff recognized the need to clarify and quantify the expression "precipitation as a small percentage of evapotranspiration." The language in 10 CFR 60.122(b)(8)(v) does not specify a "small percentage" value, so the staff have examined numerical moisture indices that have been used to develop climate classification schemes. Thornthwaite (1931) developed a precipitation-effectiveness index to classify humidity provinces ranging from wet (rain forest) to arid (desert). The independent variables used to calculate this index were mean monthly precipitation and mean monthly evaporation (Gates, 1972). Thornthwaite's 1948 classification superseded the 1931 classification in that it made use of the concept of evapotranspiration (Oliver, 1973, p. 178). The 1948 system defined nine climatic types as determined by moisture index. A 1955 revision of the original 1948 classification was carried out (Carter and Mather, 1966, p. 341-342; Mather, 1974, p. 114-115). Among other things, this revision modified the moisture index ranges for the arid to subhumid climatic types. The table of moisture regions according to Thornthwaite's 1955 climatic classification is presented below (Mather, 1974, p. 115):

CLIMATIC TYPE	MOISTURE INDEX
A Perhumid	100 and above
B_4 Humid	80-100
B_3 Humid	60-80
B_2 Humid	40-60
B_1 Humid	20-40
C_2 Moist subhumid	0-20
C_1 Dry subhumid	-33.3 to 0
D Semiarid	-66.7 to -33.3
E Arid	-100 to -66.7

The moisture index may be calculated by the following equation (Mather, 1974, p. 114):

$$I_m = 100 \, [\, (P/PE) - 1]$$

where I_m = moisture index
P = precipitation
PE = potential evapotranspiration

Using the above equation, it is possible to calculate the percentage of P/PE that corresponds to any given moisture index. A moisture index of -66.7 separates arid climates from those that are semiarid. This moisture index corresponds to a P/PE percentage equal to 33.3%. The staff consider that P/PE values of 33% or less define conditions where precipitation is a small percentage of evapotranspiration. According to Thornthwaite's 1955 climatic classification, this range of P/PE represents arid conditions.

Based on the above considerations, a conventional analysis of meteorological data will meet the intent of the requirements. 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 corrected, 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 probable that FWS evaporation significantly exceeds precipitation at the Yucca Mountain site, 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.

Limitations and Uncertainties in Meteorological Review Procedure

No key technical uncertainties have been identified with regard to this favorable condition. No limitations or uncertainties of significance are known to exist that could adversely influence the review procedures in this plan. It is expected that DOE can evaluate the presence or absence of the favorable condition in a straightforward way by documenting historical meteorological conditions in the vicinity of Yucca Mountain and quantifying the results. The techniques to determine FWS evaporation and interpret the historical precipitation record are well-established, as is the use of the Thornthwaite empirical method. DOE should be able to make the appropriate calculation and comparison of precipitation to estimates for PE and present the results in numerical and graphical form in the license application.

4.0 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/PAHB Hydrologic Transport Section
Support:	None needed

9/18

4.2 Interfaces

4.2.1 Input Information

To properly review issues related to precipitation and PE, staff will require information from other sections of DOE's LA. The needed information is shown in the following table.

Input Information	From Review Plan Nos.
Meteorological data for the Yucca Mountain region, including data on historical precipitation, temperatures, free water surface evaporation, etc.	3.1.4
Drawings, maps, or photographs showing the locations of all meteorological data collection sites in the Yucca Mountain region (meteorological stations, precipitation gages, etc.)	3.1.4
Site topography (to examine siting of meteorological stations)	3.1.1

4.2.2 Output Information

Information from this section of the LA, that will be important to other review plans, is listed in the following table.

Output Information	To Review Plan Nos.
Estimation of average annual historic precipitation for the Yucca Mountain site	3.2.2.1, 3.2.2.4, 3.2.2.9, 3.2.2.12, 3.2.4.2
Estimation of average annual free water surface evaporation rates for the Yucca Mountain site	3.2.2.1, 3.2.2.4, 3.2.2.9, 3.2.2.12, 3.2.4.2
Determination regarding the existence of this favorable condition	3.2.5
Anticipated Processes and Events to be considered in assessment of compliance with 10 CFR Part 60 performance objectives	6.1, 6.2

10/18

5.0 EXAMPLE EVALUATION FINDINGS

The staff should consider the Example Evaluation Findings presented below together with the Acceptance Criteria set forth in Section 3 when making the actual Evaluation Findings resulting from the Acceptance Review for docketing and the Compliance Reviews. The actual Evaluation Findings resulting from the Compliance Reviews, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE on the favorable condition concerning average annual precipitation and potential evapotranspiration is (is not) acceptable for docketing and compliance review.

5.2 Findings for Compliance Reviews

5.2.1 Findings for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(b)(8)(v)

Negative Finding: DOE has reported that the favorable condition is absent. DOE has thereby chosen not to take credit for the favorable condition on average annual historic precipitation as a small percentage of average annual potential evapotranspiration. Therefore, DOE cannot use this favorable condition in assessments of waste isolation to compensate for the presence of potentially adverse conditions.

Positive Finding: The NRC staff finds the conclusions presented by DOE on the favorable condition related to precipitation and evapotranspiration are acceptable and there is reasonable assurance that the regulatory requirements of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they relate to 10 CFR 60.122(b)(8)(v) will be met. The staff concludes with reasonable assurance that the average annual historic precipitation is a small percentage (33% or less) of the average annual potential evapotranspiration.

6.0 REFERENCES

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12/18

COMPLIANCE DETERMINATION STRATEGY
REVIEW PLAN 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.

13/18

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):

15/18

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.

16/18

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) (see Appendix F of the LARP for applicable text). 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.

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

17/18

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.

Contributing Analysts

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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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18|18

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Reference 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.]