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COMPLIANCE DETERMINATION METHOD FOR REVIEW PLAN NO. 3.2.2.5
POTENTIALLY ADVERSE CONDITION: FLOODING

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 GROA surface facility descriptions 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 each of the following *Compliance Reviews* 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(c)(1)

The staff will determine whether the assessment of presence or absence of flooding of the underground facility has been accomplished in an acceptable

manner, and whether 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(c)(1). 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 geology, hydrology, and meteorology of the site as related to the potential for flooding and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(c)(1). 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 the flooding potential of the GROA underground facility 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 absence of flooding of the GROA underground facility, or the extent to which its presence may have been underestimated 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 the lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(c)(1). 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 predict preclosure flooding. 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 and monitoring data for assisting review of 10 CFR 60.122(c)(1).

To make compliance determinations for these *Acceptance Criteria*, the staff must review the program of site characterization, analysis, and design implemented 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 potential flooding of the underground facility.

3.2.1.1 Hydrologic Features and Design Assumptions

To begin the *Safety Review*, staff must be familiar with basic information on designs and surface hydrologic characteristics of the site. This information is described below, and provided from those parts of the LA listed in Section 4.2.1 of this review plan:

- Drainage basin characteristics, including soil types and characteristics, vegetative cover, local topography, floodplains, and surficial and bedrock geology.
- Maps or aerial photographs showing the site location and the upstream drainage areas.
- Site geomorphological characteristics, including slopes, gradients, and processes.
- Drawings and photographs of GROA features, including the locations of portals to all shafts, ramps, tunnels, and boreholes in relation to the topography.
- Schedule for repository closure.

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Based on the above information, staff must determine the following:

(1) No unusual engineering protection measures will be relied on, and erosion, hydraulic transport of debris, and debris damming effects will be conservatively accounted for or minimized in the probable maximum flood (PMF) calculations.

(2) Any water impoundments that may be built to support site operations will be located at elevations below the portals of nearby shafts, tunnels, or ramps.

(3) During the pre-closure period, all wells and boreholes (many of which occur in the floors of washes) would be outfitted with covers that would minimize the downward flow of water to the underground facility during flash-flood events.

Acceptance Criteria for items 1 and 2 will be met if portals for shafts, ramps, and tunnels are sited above the PMF, and above any surface water impoundments that may be constructed. However, if items 1 or 2 are not met, then a review different from that described in Subsection 3.2.1.2 of this review plan would be needed. Such a review would require independent staff evaluations of engineering protection measures and the potential impacts of any water impoundments that could be sited at elevations above portals for shafts, ramps, or tunnels.

The *Acceptance Criterion* for item 3 is that DOE will have properly covered the tops of wells and boreholes. This is a conservative design approach to the pre-closure protection of wellheads from the effects of flooding. Pre-closure flood events of large magnitude could occur, including hydraulic transport of debris. However, it is expected that even if borehole casings should be damaged or eroded by floods, flowpaths would not be created that could conduct large inflows to the repository.

3.2.1.2 Review Procedure for Flooding Potential

DOE can acceptably show that this PAC is absent if its GROA design shows that the lowest part of all portals for shafts, ramps, and tunnels have been located above the level of the calculated PMF. The following four-step procedure will be used by the staff to perform the *Safety Review*.

Step 1 -- Confirm Portal Elevations for GROA Shafts and Ramps

Staff shall examine general information on the GROA design submitted by DOE in review plans 4.1.1 ("Description of GROA Structures, Systems, and Components: Surface Facilities") and 4.1.2 ("Description of GROA Structures, Systems, and Components: Shafts and Ramps") of the LA. Staff shall determine if the following *Acceptance Criterion* has been met: The elevations of portals to all shafts, ramps, and tunnels of the GROA are provided in tabular form, or are depicted on engineering drawings of the GROA.

Step 2 -- Review Estimates for Probable Maximum Precipitation (PMP)

Staff shall review DOE's estimates of the PMP that would be used to calculate the

PMF. The PMP is defined in ANSI-2.8 (ANS, 1992; p. 2) as:

> "[t]he estimated depth of precipitation for a given duration, drainage area, and time of year for which there is virtually no risk of exceedance. The probable maximum precipitation for a given duration and drainage area approximates the maximum that is physically possible within the limits of contemporary hydrometeorological knowledge and techniques."

Generalized estimates of PMP for the United States have been prepared by the National Weather Service (NWS). The NWS has also made site specific PMP estimates for Federal water projects. As an *Acceptance Criterion*, Hansen *et al.* (1977) is an acceptable reference for DOE to use to estimate reasonable PMP values for the Yucca Mountain site. Estimates should include appropriate adjustments to the PMP based on the areas of drainage basins, rainfall durations, and land surface elevations. An additional *Acceptance Criterion* applies to cases where times of concentration are very short, 15 minutes or less. In such cases, it would be acceptable to calculate the PMP using modified methods described by Nelson *et al.* (1986, p. 10, Table 2.1).

Step 3 -- Review Estimate of the PMF

Staff shall examine DOE's calculations of the PMF. The PMF is defined in ANSI-2.8 (ANS, 1992; p. 1) as:

> "[t]he hypothetical flood (peak discharge, volume, and hydrograph shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of probable maximum precipitation and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt."

HEC1 (USCOE, 1974 and 1985) is an acceptable model for DOE to use to compute the PMF in various drainage basins at Yucca Mountain. *HEC2* (USCOE) is acceptable for delineating water surface profiles. Input parameters for *HEC1* include runoff and infiltration relationships, time of concentration (time of concentration is the amount of time required for runoff to reach the outlet of a drainage basin from the most remote point in that basin), lag times, and PMP distributions. The NRC staff recommends, based on the steepness of basin slopes at Yucca Mountain, that conservative values of input parameters be selected. This is especially true for input parameters, such as time of concentration, that are based on empirically derived formulas. If a calculation method requiring time of concentration is used, field studies to determine overland and gully flow velocities may provide the best estimates for time of concentration. Kirpich's formula (Kirpich, 1940), or other applicable empirical methods, can be used if the time of concentration is conservatively chosen. If the method uses a unit hydrograph, the likely non-linear transformation of runoff to streamflow should be recognized and accounted for. If a kinematic-wave method is used, attention should be given to the conservatism of the friction coefficient and the need for proper representation of small-channel geometry. A field investigation is recommended for the use of the kinematic flow method.

The staff recommends that DOE use a velocity-based method (such as the Kirpich method, as discussed by Nelson *et al.*, 1986) to compute time of concentration.

The staff considers that methods based on flow velocities are more appropriate for the short and steep surface-water basins at the Yucca Mountain site. Some other methods may tend to overestimate the time of concentration because they were designed for larger drainage basins with lower overall hydraulic gradients. Overestimating the time of concentration can result in non-conservative PMF estimates.

The NRC staff should compare DOE's PMF estimates to estimates developed by the U.S. Bureau of Reclamation (Bullard, 1986), as appropriate. Further, the staff should compare DOE estimates to historic flood peaks in the southwestern United States, to provide assurance that the PMF estimates are reasonable.

The *Acceptance Criterion* that DOE must meet is that the evaluation of PMF is based on the site-specific PMP and the guidance contained in ANS (1992).

Step 4 -- Compare the Portal Elevations for GROA Shafts and Ramps with the PMF

DOE can acceptably show that this PAC is absent if the GROA design demonstrates that the portals for all shafts, ramps, and tunnels have been located above the level of the calculated PMF, and above any surface water impoundments that may be constructed. Confirmation that the portals are all above PMF boundaries comprises the final *Acceptance Criterion* in the staff's *Safety Review*. If it appears that a portal may be susceptible to a PMF, staff should obtain field confirmation before reaching a negative finding. Based on its pre-licensing consultations, the staff is expected to know well in advance of the LA submittal whether the locations of portals are susceptible to PMF conditions.

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(c)(1)

The flooding or precipitation event for DOE to evaluate in connection with this PAC should be one for which there is reasonable assurance of non-exceedance during the pre-closure period. An event with an exceedance probability of 0.01 per year (return period of 100 years, or as commonly termed, "the 100-year flood") would have a 63 percent chance of being equaled or exceeded during the next 100 years (Nelson et al., 1983, p. 5). The probability of such a flood not occurring would thus be only 37 percent. The return period of a flood for a given probability of non-occurrence can also be calculated. For example, for a 100-year design and a 99 percent probability of non-occurrence, the design flood would have a recurrence interval of approximately 10,000 years. The staff considers that the consequences of flooding the repository during operations could be so significant that a 99 percent probability of non-exceedance is desirable to provide the required reasonable assurance.

Statistical methods could be used, if adequate data were available on historical flooding at Yucca Mountain. An alternate and preferred approach is to choose an event that is based on site-specific extreme meteorological and hydrological characteristics. The PMF and the PMP, as defined by the ANS (1992, pp. 1 and 2), are events of sufficiently low likelihood. The NRC staff concludes that there is reasonable assurance that events larger than the PMP and PMF will not likely

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occur during the pre-closure period at Yucca Mountain. Therefore, if portals to all shafts, tunnels, and ramps are sited above the calculated PMF, there will be reasonable assurance that flooding of the underground facility will not occur during the pre-closure period.

A conventional analysis of flood flows and levels in on-site channels for floods up to the PMF can be expected to meet the intent of the requirements. The fact that the flooding analysis will be tied to the engineering design for pre-closure operations rather than the overall performance assessment eliminates the need to determine probabilities for extremely rare floods (beyond the PMF). The conservatism inherent in standard flood determination procedures will also assure that the requirements are met.

Limitations and Uncertainties in PMF Procedure

Models such as *HEC1* and *HEC2* are widely used by the hydrologic engineering community and have extensive documentation of their application and validity. The staff are not aware of any limitations in using these models to compute PMF discharges and water surface profiles. The models are subject to the uncertainties in field data used to construct site models. For this reason, use of conservative values for input parameters have been recommended.

4.0 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/PAHB	Hydrologic Transport Section
Support:	DWM/PAHB	Performance Assessment and Health Physics Section

4.2 Interfaces

4.2.1 Input Information

To properly review compliance with regulatory requirements for flooding, 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.
Surface Hydrology	3.1.2
Site Geology, Topography and Geomorphology	3.1.1
Estimates for Probable Maximum Precipitation	3.1.4

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Input Information	From Review Plan Nos.
Drawings and photographs showing GROA design features, including portal elevations for GROA shafts, ramps, and tunnels	4.1.1, 4.1.2

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 the PMP for the Yucca Mountain site.	4.2
Delineation of floodplain boundaries for the PMF near portals for shafts, ramps, and tunnels	4.2, 4.3, 4.4
Determination regarding the existence of this PAC	3.2.5
Anticipated Processes and Events to be considered in assessment of compliance with 10 CFR Part 60 performance objectives	4.5, 5.4, 6.1, 6.2, 6.3

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 Sample Finding for Acceptance Review

The NRC staff finds the information presented by DOE on the PAC concerning pre-closure flooding of the underground facility is (is not) acceptable for docketing and compliance review.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(1)

The NRC staff finds the conclusions presented by DOE on the PAC related to pre-closure flooding of the underground facility are (are not) acceptable and there

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is (is not) 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(c)(1) will be met. The DOE has shown that the portals of all tunnels, ramps, and shafts are (are not) located above the local probable maximum flood for each drainage area in which they are located. Therefore, the staff concludes with reasonable assurance that the maximum flood resulting from the probable maximum precipitation will not (will) cause flooding of the underground facility as designed.

If DOE has acceptably demonstrated that portals for all tunnels, shafts, and ramps are above the PMF, 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 demonstrate the absence or acceptably describe the presence of the PAC and encompass appropriate ranges of relevant parameters.

(2) DOE can demonstrate that the extent of characterization is sufficient to define flooding in the geologic setting and to assure that potential effects on critical pathways for radionuclide migration have been adequately described.

(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 potential effects of underground facility flooding are well enough understood to be appropriately considered in the 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.

6.0 REFERENCES

ANS, 1992, "American National Standard - Determining Design Basis Flooding at Power Reactor Sites," American Nuclear Society Standards Committee, Working Group ANS-2.8, ANSI/ANS-2.8-1992, 54 p.

Bullard, K. L., 1986, "Comparison of Estimated Probable Maximum Flood Peaks with Historic Floods," U. S. Department of the Interior, 165 p.

Hansen, E. M., F. K. Schwarz, and J. T. Riedel, 1977, "Probable Maximum Precipitation Estimates", Colorado River and Great Basin Drainages: Hydrometeorological Report No. 49, U. S. Army Corps of Engineers, prepared by the Office of Hydrology, National Weather Service, Silver Spring, MD, 161 p.

Kirpich, Z. P., 1940, "Time of Concentration of Small Agricultural Watersheds," Civil Engineering, Vol. 10, No. 6 (June).

Nelson, J. D., S. R. Abt, R. L. Volpe, D. van Zyl, N. E. Hinkle, and W. P. Staub, 1986, "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium

Mill Tailings Impoundments," NUREG/CR-4620, prepared by Colorado State Univ. and Oak Ridge National Laboratory for U.S. Nuclear Regulatory Commission, 145 p.

Nelson, J. D., R. Volpe, R. E. Wardwell, S. A. Schumm, and W. P. Staub, 1983, "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments," NUREG/CR-3397, prepared by Colorado State Univ. and Oak Ridge National Laboratory for U.S. Nuclear Regulatory Commission, 163 p.

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

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. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

USCOE (U.S. Army Corps of Engineers), "Water Surface Profiles," Computer Program 723-X6-L202A, HEC-2, Hydrologic Engineering Center, Davis, California [continuously updated and revised].

USCOE (U.S. Army Corps of Engineers), 1981, "Flood Hydrograph Package," Computer Program 723-X6-L2010, HEC-1, Hydrologic Engineering Center, Davis, California.

USCOE (U.S. Army Corps of Engineers), 1985, HEC-1 Flood Hydrograph Package: Users Manual, Computer Program 723-X6-L2010, U.S. Army Corps of Engineers, Water Resources Support Center, 190 p.